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TABLE OF CONTENTS

VOLUME XXXVII

NUMBER 1—JANUARY

Illinoian Drift Region of Northeast Central Ohio ..... *George W. White* 1
Morphology of the Forelimb of the Mole (*Scalops aquaticus* L.) in Relation to its Fossorial Habits ..... *Linden F. Edwards* 20
The Comparative Anatomy of the Thyroid and Adrenal Glands in Wild Animals ..... *Robert Crile* 42
Note on the Production of Fruiting Bodies of *Coprinus micaceus* in Culture, *S. S. Humphrey* 61
Book Notices 19, 64

NUMBER 2—MARCH

Some Cytological Observations on Peripheral Myelinated Nerve Fibers as Observed by the Polarized Light Method, *H. E. Setterfield and H. M. Weaver* 65
The Detection of Sex-Linkage in Families Collected at Random, *Chas. W. Cotterman* 75
An Experiment With Heavy Water, *John S. Richardson and G. Raymond Hood* 82
A Study of the Leeches of Michigan, With Key to Orders, Suborders and Species ..... *John A. Miller* 85
The Daily Rate of Growth of Toe Nails, *Linden F. Edwards and Ralph G. Schott* 91
Studies on Fresh-Water Bryozoa. V. Some Additions to Canadian Fauna, *Mary D. Rogick* 99
Some New Species of Ballana (Homoptera, Cicadellidae) .. *Dwight M. DeLong* 105
Book Notices 84, 98, 104, 124, 125, 126

NUMBER 3—MAY

Indication of Unit Factor Inheritance in Data Comprising but a Single Generation ..... *Chas. W. Cotterman* 127
The Portersville Member of the Conemaugh Formation in Muskingum County, Ohio ..... *Wilson M. Laird* 141
The Urinary Elimination of Boric Acid, *Alexander K. Presnell and Harvey C. Brill* 147
The Anatomy of the Digestive System of *Oncopeltus fasciatus* Dall. (Heteroptera: Lygaeidae) ..... *Charles W. Hood* 151
Some New Species of Idiocerus (Homoptera—Cicadellidae), *Dwight M. DeLong and J. S. Caldwell* 161
Some Effects of Temperature on the Development and Oviposition of *Microbracon hebetor* (Say) ..... *F. H. Harries* 165
The Embryo Sac of *Eragrostis cilianensis* (All.) Link. A New Type Embryo Sac and a Summary of Grass Embryo Sac Investigations ..... *E. L. Stover* 172
An Annotated List of the Dragonflies (Odonata) of Ohio ... *Donald J. Borror* 185
Book Notices 197

NUMBER 4—JULY

Report of the Forty-seventh Annual Meeting of the Ohio Academy of Science ..... *William H. Alexander* 201

Grants in Aid of Research 247

Leeches of Southeastern Missouri ..... *Marvin C. Meyer* 248

Insect Hosts and Nymphal Development of *Podisus maculiventris* Say and *Perillus bioculatus* F. (Hemiptera, Pentatomidae) ..... *B. J. Landis* 252

Additions to the Revised Catalog of Ohio Vascular Plants, V. ..... *John H. Schaffner* 260

Two New Species of *Osbornellus* ..... *Dwight M. DeLong and Lawrence Beery* 266

Book Notices 251, 259, 265

NUMBER 5—SEPTEMBER

Examples of Orthogenetic Series in Plants and Animals. Studies in Determinate Evolution X ..... *John H. Schaffner* 267

Additional Notes on *Argulus trilineatus* (Wilson) ..... *O. Lloyd Meehean* 288

Some Cladoniae from Southwestern Ohio. Cladoniae from Clermont, Brown and Adams Counties ..... *M. Fulford* 295

New Southwestern Buprestidae and Cerambycidae with Notes ..... *Josef N. Knull* 301

Book Notices 287, 294, 300, 311–314

NUMBER 6—NOVEMBER

Symposium on Hormones:

Foreword ..... *F. A. Hitchcock* 315

The Growth Hormones Found in Plants ..... *George S. Avery, Jr.* 317

Responses of Plants to Hormone-Like Substances ..... *P. W. Zimmerman* 333

Nervous System and Internal Secretion ..... *Leon Asher* 349

The Gastrointestinal Hormones or Autacoids ..... *A. C. Ivy* 355

The Prolongation of Insulin Action ..... *C. H. Best* 362

The Male Sex Hormone—Some Factors Controlling Its Production and Some of Its Effects on the Reproductive Organs ..... *Warren O. Nelson* 378

The Female Sex Hormones ..... *Hans O. Haterius* 394

The Thyroid Hormone ..... *David Marine* 408

The Hormones of the Adrenal Gland ..... *Frank A. Hartman* 427

The Hormones of the Anterior Pituitary ..... *Oscar Riddle* 446

Book Notices 348, 354, 377, 393, 407, 426, 445, 464

Index to Volume 465

THE OHIO JOURNAL OF SCIENCE

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ILLINOIAN DRIFT REGION OF NORTHEAST CENTRAL OHIO

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INTRODUCTION

The purpose of this paper is to discuss the pre-Wisconsin drift region in northeast central Ohio, including northeastern Licking, southwestern Coshocton, eastern Knox, southeastern Richland, and southwestern Ashland counties, (Fig. 1).[1] This area is the northern part of the area of Illinoian drift, which lies east of the Scioto lobe of Wisconsin drift and south of the Killbuck lobe (9, Fig. 1)[2] of Wisconsin drift. To the north, the Illinoian drift occupies the re-entrant angle between these two Wisconsin lobes. The area lies wholly within the Allegheny Plateau which was here dissected to maturity, and which had a relief of 200 to 400 feet before Illinoian drift masked the pre-Illinoian erosion topography in varying degrees—at most places but slightly, but at some, however, mainly in wide valleys, it effectually covers the bedrock topography and controls the topographic expression.

CORRELATION

The drift of northeastern Licking, southeastern Knox, and southwestern Coshocton counties was described as Illinoian by Leverett who traced the Illinoian drift from Illinois across Indiana and southern Ohio to this area (2, pp. 253–261). His correlation is used here. Although Leverett regarded the drift of much of northeastern and north central Knox County as Wisconsin, the studies of the present writer show that this drift has the same characteristics as, and can be traced directly into, the drift of southeastern Knox County. It must, therefore, be Illinoian, and is so shown on the map, Fig. 1.

[1]The topographic maps of the area are Shauk, Perrysville, Loudonville, Gambier, Brinkhaven, Newark, and Frazeysburg.

[2]References are to bibliography at end of paper.

THE TILL

The unoxidized, unleached, fresh Illinoian till is a strongly calcareous, bluish gray, pebbly clay, of a somewhat silty character. Pebbles and cobbles are common, but boulders are rare. Few boulders larger than two feet in greatest diameter were seen. The percentage composition of one half

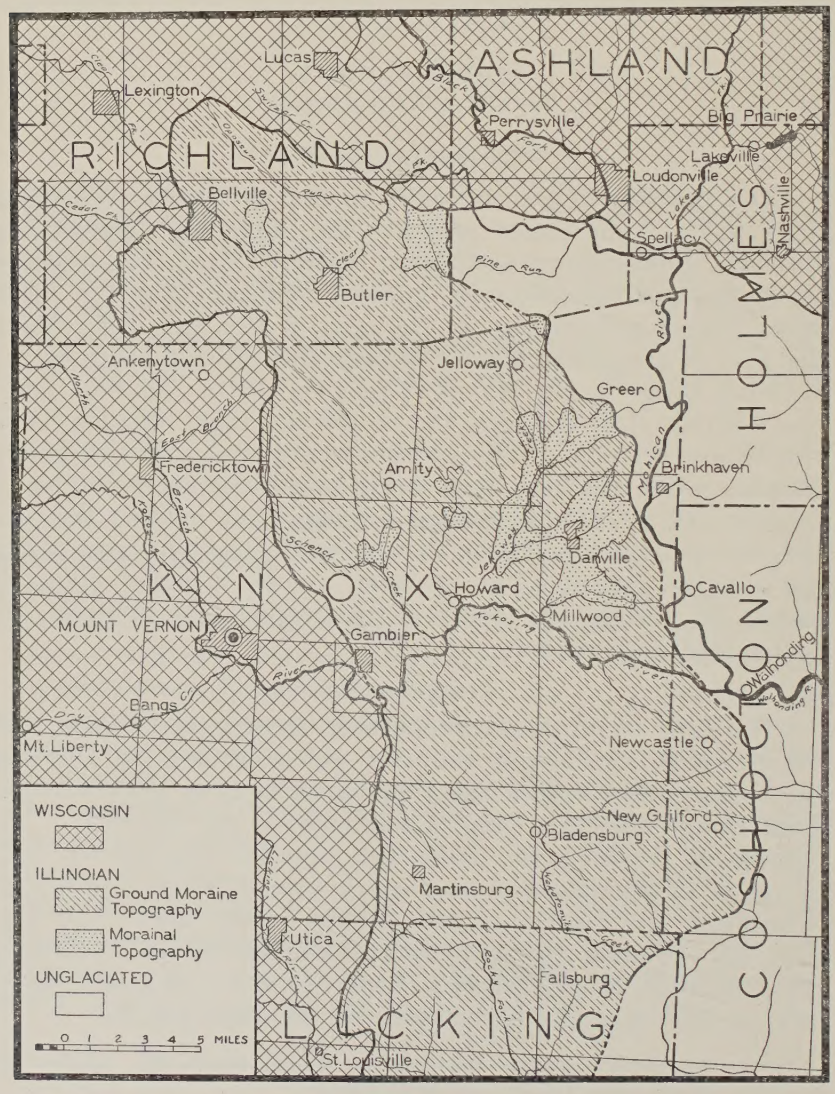

FIG. 1. Map showing glacial geology of a part of north central Ohio.

to two inch pebbles from unaltered till in northeastern Section 7, Perry Township, Coshocton County, was determined as:

Limestone	46
Sandstone	32
Carbonaceous shale and coal	7
Flint	6
Granite	2
Quartzite	7
	100

The limestone, constituting 46 per cent, came from southern Ontario or the Erie basin. The sandstone, carbonaceous material and flint came from the Waverly and Pottsville formations of the Allegheny Plateau and travelled from one to a maximum of 40 miles. The igneous and metamorphic material came from the Canadian Shield.

The upper part of the till is at all places altered by agencies of weathering. A trustworthy average section of the weathered upper part can hardly be given, because comparatively few exposures reveal the unaltered till, but the following section is based on the data at hand:

		Feet
Zone 3.	Till: light brown, porous, oxidized, leached	8
	Sharp contact with Zone 2.	
Zone 2.	Till: brown, oxidized, unleached	7
	Irregular gradation into Zone 1.	
Zone 1.	Till: grayish-blue, silty, calcareous, moderately hard, pebbly	0–25+

Zone 1 is the unaltered unoxidized, unleached till that has been described. Zone 2 is the oxidized, unleached zone and Zone 3 is the oxidized, leached zone which grades into soil near the surface.

The oxidized Illinoian till of Zone 2 is brown, the exact shade varying from medium to light, depending on the amount of moisture present. This oxidized, unleached zone has a thickness of from 6 to 12 feet and grades with an uneven contact into the unoxidized blue till below, the oxidation having advanced more rapidly where the till is more porous. It is similar in texture and mineral content to the blue till of Zone 1. This unleached, oxidized zone in the till of Illinois has been called "Horizon 4" by Leighton and MacClintock (1).

The leached, oxidized Illinoian till of Zone 3 is light brown in color, the shade decreasing in intensity toward the surface. This zone is looser and more porous than Zones 1 and 2, because of the solution of limestone pebbles and finer calcareous material and of the entrainment of finer rock particles by ground water.

This leached zone has a thickness of from 5 to 15 feet, and rests with a sharp contact upon the oxidized, unleached zone below. In Illinois (1, Fig. 1), this zone has been divided into Horizons 1, 2, and 3, but in that part of Ohio here discussed the distinction between "Horizon 2" and "Horizon 3" is not immediately apparent, in part, possibly, because the till is so well drained.

The thicknesses of Zones 2 and 3 vary greatly from place to place because oxidation is faster in more porous till and in those portions having better drainage, and to the removal of the oxidized zone by erosion at the surface. On steep slopes this removal may keep pace with, or exceed, leaching. The following section was observed on the road cut along the state highway in the northeastern part of Section 7, Perry Township, Coshocton County, one-fourth mile northeast of New Guilford:

	Ft.	In.
Soil and silttil (1, p. 41): dark brown, sandy, leached	2	10
Clay: brown, pebbleless, leached	0	6
Clay: gray, pebbleless, leached	1	1
Clay: gray, pebbleless, unleached	0	6
Till: brown, only moderately pebbly, silty, oxidized, unleached	6	4
Till: dark blue, silty, only moderately pebbly; grades into above fairly sharply	4	0

This section is only one-half mile west of the glacial boundary and is unusually thick for a location so close to the glacial border.

Along the Martinsburg-Bladensburg state road in Clay Township, Knox County, one and one-half miles west of the village of Bladensburg, the following section was measured:

	Ft.	In.
Soil and Silttil: buff to ashen, fine-grained, silty; much weathered	1	6
Till: brown, silty, thoroughly oxidized, leached, pebbly; grading upward to yellow; with some dark stains along joints in lower part	4	0
Till: yellow-brown, sandy, very pebbly, unleached; with white spots and limestone pebbles	5	4
Till: gray-blue, sandy, pebbly, unleached	2	0

In a new road cut along the Mt. Vernon-Coshocton road in western Howard Township, one-quarter mile east of Monroe Mills, 12½ feet of yellow, leached, porous till, with many sandstone cobbles and pebbles included, resting on Waverly (Blackhand) sandstone, were exposed. This is more than usual depth of leaching and is attributed to the fact that here the till is quite sandy and porous. The variation in depth of leaching over short distances, especially where erosion may

have been active on slopes, is shown by the following section measured along the same road one mile west of the above exposure:

	Ft.	In.
Till: yellow, sandy, leached	4	6
Till: yellowish-brown, silty, hard, unleached	7	6
Till: blue-gray, hard, pebbly, strongly calcareous	5	0

A section measured in a newly excavated road cut one-half mile east of Amity in eastern central Section 21, Pike Township, shows only five and one-half feet of unleached till, and indicates that part of the leached zone has been removed. The section is as follows:

	Ft.	In.
Till: yellow, weathered, leached	5	6
Till: yellowish-brown, silty, strongly calcareous	6	6
Till: dark blue, silty, pebbly, strongly calcareous	1	0

The leached zone is from seven to over twelve feet thick in Pike and Brown townships in northern Knox County. In Jefferson and Union townships, northeastern Knox County, the depth of leaching varies generally from six to eight feet. Probably the till here has suffered more erosion, and the surface is now being eroded away faster than leaching can penetrate downward.

The Illinoian till is thin and discontinuous in much of Worthington and eastern Jefferson townships of Richland County. It is thicker and more generally present in central and central western Jefferson and central southern Washington townships, where deep exposures may disclose unaltered blue till. An excellent section was exposed by the relocation of the Bellville-Mansfield state road, two miles north of Bellville in central Section 4, Washington Township, where the following divisions were measured:

		Ft.	In.
6.	Soil: buff to ashen gray, strongly weathered, silty, almost pebbleless.	2	0
5.	Till: very dark brown with black stains along joints, with some pebbles, leached, strongly oxidized	2	3
4.	Till: yellow-brown, leached, oxidized, sandy with pebbles; becomes more buff upward and grades into No. 5	6	4
3.	Till: brown, hard, oxidized, unleached, very pebbly; with darker stains along joints and an uneven contact with No. 2	6	6
2.	Till: gray-blue, hard, unevenly oxidized along joints	4	0
1.	Till: blue, hard, pebbly, with boulders up to 4 feet in diameter; to road level	15	0

It may be noted that 1 and 2 correspond to "Horizon 5," and 3, 4, 5, and 6 to "Horizons" 4, 3, 2, and 1, respectively (1).

ILLINOIAN BOUNDARY

The outer limit of Illinoian drift extends in a general northerly direction across Licking County, swings eastward to include the southwestern part of Coshocton County and thence northwestward across northeastern Knox and southwestern Ashland counties to disappear underneath the Wisconsin drift in southeastern Richland County.

The Illinoian boundary varies in distinctness. In some places it is marked by continuous drift which influences the topography; in places by only scattered boulders and pebbles; and in still other places it is only conjectural and must be mapped by extending a line between two known points. Road cuts, ravines, and fields were carefully examined, and, in order to be sure that the most eastern foreign pebbles or cobbles were actually found, a belt of from two to more than five miles beyond the boundary was carefully searched.

The Illinoian boundary shown on the map, Fig. 1, agrees with that of Leverett (2, pl. 13) in Licking and southwestern Coshocton counties, but to the north the present investigation shows the Illinoian boundary to be considerably west of that mapped by Leverett. Extended search failed to bring to light any glacially derived material east of the Mohican River in northwestern Coshocton County or in southwestern Holmes County, (4, p. 437).

Licking County.—The Illinoian boundary in that part of Licking County included in Fig. 1, crosses from the northern part of Perry Township into Fallsbury Township which it crosses in a northeasterly direction to the corner of that township. The boundary from the great glacial dam at Hanover to Fallsburg in northeastern Licking County is exceedingly vague. Erosion has removed almost all of that Illinoian drift not only from the region near the mapped boundary, but from the territory several miles to the west. Indeed, the Illinoian drift found closest to the conjectural boundary mapped south of Fallsburg, was one mile north-northwest of Hickman in northern Mary Ann Township and in central Section 21, Eden Township. It may be possible that south of Fallsburg the Illinoian boundary as drawn is too far east.

One mile northeast of Fallsburg, in northwestern Section 12, Fallsbury Township, a few cobbles and pebbles of resistant foreign rocks, found on the north side of a road cut, are taken as the limit of ice advance; the location of these is shown in

Fig. 1 by a solid line. Northeast from this locality for several miles, the boundary is again indistinct.

Coshocton County.—The boundary enters Coshocton County in the southwestern corner of Perry Township and passes northeastward to Winding Fork. Thence it passes in a general northerly direction across Perry Township into Newcastle Township to the edge of the upland south of the Walhonding River. Across these townships the drift extends almost, or quite to the boundary at numerous places, although it becomes quite thin along the outer margin.

One-half mile east of Newcastle the boundary turns sharply to the northwest and passes into a more rugged area along the Kokosing valley for two and one-half miles northwest to the Coshocton-Knox county line, one-half mile north of the Kokosing River. Erosion has removed all the drift from the steep valley walls of the Kokosing valley, and even from the narrow interstream areas, so that foreign pebbles are absent for some distance back from where the ice margin rested, as mapped by a broken line on Fig. 1.

Knox County.—North of the Kokosing valley the Illinoian boundary lies only one to two miles west of the Mohican River valley for a distance of about ten miles. The Illinoian ice margin was apparently the factor which determined the location of this part of the Mohican River (8). The boundary enters Knox County in the southeast corner of Union Township in Section 21, where igneous pebbles exist along the top of the ridge. North of Section 21, the boundary is indefinite for about three miles to Tager Valley, where areas with constructional topography make a fairly definite boundary. Thick deposits of drift mark the boundary northward into Jefferson Township. In Section 8, Jefferson Township, the border crosses a preglacial valley, and its course is especially clear in central and northwestern Section 8, where gravel knolls are prominent at the border (Fig. 2). Thence the drift limit runs in a general northwesterly direction to the northeastern corner of Brown Township.

In the northeast corner of Brown Township, one and one-half miles northeast of Jelloway, a morainic ridge, about a mile long extends across a preglacial valley and forms a water parting in the old valley. The drainage of the portion to the northeast was diverted during the ice occupancy southward across a former divide to Shadley Valley Creek. The Columbus-

Cleveland highway crosses the south end of this moraine one and one-half miles northeast of Jelloway, and for one-half mile northeast the highway skirts the pre-Illinoian valley which is dammed by the drift ridge.

Ashland County.—From the northeastern corner of Brown Township, Knox County, the boundary runs north-northwest across southwestern Hanover Township, Ashland County, to the west line of Section 19, on the Ashland-Richland county line. The boundary is indefinite and may be mapped only by examining the fields and road cuts for foreign pebbles, there being no till for a mile or even two miles or more inside the boundary.

Richland County.—The Illinoian boundary in Worthington Township is located just west of the county line. A considerable thickness of Illinoian drift extends almost or quite to the boundary which is topographically distinguishable against the hills to the east. The Illinoian boundary passes under the east-west trending Wisconsin drift boundary in western central Section 12, about 300 yards west of the county line. Here the overlapping of the Wisconsin moraine makes separation of the moraines of the two ages very difficult.

THE ILLINOIAN-WISCONSIN BOUNDARY

The inner boundary of the Illinoian drift region is the outer boundary of the Scioto lobe of the Wisconsin drift region. It is 10 to 13 miles west of, and roughly parallel to the outer boundary of the Illinoian drift (Fig. 1). The northern boundary of the Illinoian area is made by the overlapping edge of the Killbuck lobe of the Wisconsin drift sheet. Brief descriptions of these boundaries have been published (6, 7).

AREAS OF GROUND MORAINE TOPOGRAPHY

The Illinoian drift region is in large part an area of ground moraine (Fig. 1), but small areas of morainal topography and of kames and kame terraces are present. Most of the area consists of a maturely dissected bedrock topography with a veneer of drift which mantles the surface and forms minor relief features. In some localities the pre-Illinoian bedrock topography is more masked than in others. In many localities drift was either never deposited or has been considerably eroded from hilltops. Most of the Illinoian drift region here described falls generally in MacClintock's type 3 (3, Figs. 2 and 8).

FIG. 2. Kames near Illinoian boundary in central Jefferson Township, Knox County, two miles southwest of Greer. Bed-rock hills in distance with thin veneer of till.

FIG. 3. Illinoian ground moraine one mile southeast of Newcastle, Coshocton County.

Fig. 4. Knolls of Illinoian drift in northwestern Jefferson Township, Richland County, two miles east of Bellville. The most distant hills are only thinly covered with drift.

Licking County.—The eastern part of Washington Township and the western part of Eden Township are quite generally drift covered, although bedrock frequently outcrops in gullies and along the roads, especially near the tops of the hills. In eastern Eden Township and western Fallsbury Township, the drift is very thin and discontinuous, and confined to scattered boulders and small masses of till on the ridges. A little kame gravel is present in the valley of Long Run, central Section 21, Eden Township. Swells of gravelly till are present along the county line in Section 2, Eden Township.

Coshocton County.—The glaciated part of Coshocton County is more generally till covered than is the territory nearest the glacial boundary farther to the southwest. Indeed, the till is so thick in parts of these townships, that the topography has been somewhat subdued by the drift control. The surface is rolling in long smooth sweeps. The relief varies from 50 to 100 feet, the slopes commonly having a grade of 100 feet or less per mile except along the valleys of the eastward flowing streams where the relief is more pronounced. Fig. 3 shows a part of this rolling plain south of Newcastle.

Knox County.—The Illinoian surface of that part of Knox County south of the Kokosing River offers considerable contrast to the Illinoian surface north of the river. The surface is generally till covered, and in many places, especially in the valley of Wakatomika Creek, constructional topography is evident. Bedrock is exposed, however, on many of the slopes, which is in distinct contrast to the Wisconsin drift region to the west where the till is a great deal thicker and where bedrock is much less generally exposed.

The Illinoian region is much more rugged north of the Kokosing River than the rolling areas south of the river. Three factors seem to be responsible: (1) the pre-Illinoian surface was an area of mature dissection having a bedrock relief of 200 to 400 feet and possibly somewhat greater; (2) only enough till was deposited in most places to veneer the bedrock topography; and (3) the greater relief, and steeper slopes of the bedrock topography have allowed erosion to remove much of the thin till sheet that was deposited. In a few small areas sufficient drift to cover the bedrock remains, making rolling areas of small extent.

In Union, Howard, southern Brown, and southwestern Jefferson townships the drift is generally discontinuous, except

in certain valleys where morainal areas exist. The general aspect is one of wide valleys with undulating till surfaces, flanked by valley slopes, commonly of bedrock. The hilltops preserve evidence of glaciation—till where they are broad, but only foreign cobbles and boulders where they are narrow. In Monroe and Pike townships the Illinoian drift is more continuous although bedrock often appears at the surface on the upper slopes and hilltops. In the central part of Pike Township, in the headwaters of Little Schenck Creek, the slopes are more undulating than is common, and the topography is quite constructional. The till here is unusually gravelly. To the north, in the vicinity of North Liberty, the till is thick and somewhat gravelly. Here is an upland area of about one-half a township that has thicker till and more billowy surface than usual, being similar to the area south of the Kokosing River.

Richland County.—In the Illinoian area in Richland County the till is generally thin and discontinuous except in the Davis Basin and in a few of the valleys. An area east of Butler (2, pp. 393–394) has been described as driftless, but the present writer has found scattered boulders and occasional till patches in this area in southern Worthington Township. In Jefferson Township both north and south of Bellville, the Illinoian drift is thicker than it is to the east. Considerable drift, sometimes with an undulating surface, remains in the valleys and even on some of the hilltops.

AREAS OF MORAINAL TOPOGRAPHY

Only a few areas showing definite morainal topography exist in the Illinoian drift region and these areas are almost entirely confined to wide pre-Illinoian lowland areas mostly near the Illinoian border (Fig. 1). It is believed that morainal topography was rarely, if ever, developed on the uplands of this rugged area. This interpretation is supported by the fact that in those parts of the Wisconsin region which are equally rugged, morainal topography is usually found only in the old valley areas (4, 5). The position of these depositional features in the old valley courses, from which the pre-Illinoian streams were in most cases diverted, has protected them from active erosion such as similar features would have suffered on the higher slopes or over the upland, and has permitted constructional features to persist to the present. Their preserva-

tion was still further aided by the gravelly character of the morainal drift which allows greater percolation of the rainfall, thus preventing excessive surface erosion.

These irregular areas of Illinoian morainal topography are explained by the writer as deposits made by melting of stagnant ice, and not as end moraines. They are similar to previously described Wisconsin morainal deposits in similar topographic positions (4, 5).

Danville Area.—The largest area of Illinoian morainal topography is in a plexus of wide pre-Illinoian valleys in northeastern Knox County, in Union, and southwestern Jefferson townships. The topography is indeed unusually morainal for Illinoian, and Leverett (2, p. 383) described it in 1902 as Wisconsin terminal moraine. An Illinoian age is indicated, however, by the fact that the region between this morainal area and the Wisconsin boundary shown on Fig. 1 is discontinuously mantled by typical Illinoian ground moraine.[3]

West and southwest of Danville, on either side of the valley of East Branch, low swells of gravelly till are plastered against the valley walls to a height of about 100 feet above the wide valley bottom. Above this height bedrock outcrops are common. The unnamed valley from Danville south to Millwood is filled with kames and with swells of sandy till containing pockets of gravel. To the southeast of Danville a prong of the moraine extends over into the headwaters of Flat Run and continues to within less than two miles of the drift border. The sides and bottom of the valley of Flat Run from its head almost to Flat Run School are covered with low swells, made up of silty till with some pockets of gravel.

A group of conspicuous kames, some of them 100 feet high, cover about a square mile of the area one to two miles south of Danville. The gravel is medium-grained at places and coarse at others, with many six- to eight-inch cobbles and a few boulders up to two feet in diameter.

The valley of East Branch northeast of Danville is moderately broad and the slopes have a constructional topography. Many sections of till are exposed along the Danville-Greer road, but most of them are not deep enough to expose unaltered blue till.

---

[3]Similar extensive areas of morainal topography of Illinoian age are well developed in the valley of Jonathan Creek in southwestern Muskingum County and northeastern Perry County.

Broad swells with a relief of 20 to 30 feet begin one to two miles east of Danville, south of the railroad, and extend east to the glacial boundary. Here several large kames rise from 50 to 100 feet near the glacial boundary. The gravel composing them is cobbly to medium-grained gravel, with some pockets of fine gravel and sand. The bedding is irregular and slumped, and it dips at high angles in various directions. Large masses of blue, silty till are included in the gravel. Eastward from these kames, for about three-fourths of a mile between the Pleasant Valley School and the southwestern corner of Section 22, Wisconsin outwash has filled the Mohican valley and probably slightly overlaps the Illinoian drift. Though this outwash might appear to be associated with the Illinoian terminal moraine, investigation shows very definitely that it is a part of a Wisconsin valley train deposited in the Mohican valley. Remnants of this valley train can be traced from the Wisconsin boundary, north of the Knox-Holmes county line (4, Fig. 2), southward to the mouth of the Mohican River, and thence down the Walhonding valley.

Morainal topography is well developed in the wide valleys of Jelloway Creek and its tributary, Dowd Creek, in eastern Brown and southwestern Jefferson townships. Knolls partly fill a pre-Illinoian valley carved by a stream which rose east of Greer and flowed southwest. These deposits form the present water parting between the westward flowing east fork of Dowd Creek and a small eastward flowing tributary to the Mohican River which now drain the valley. Morainal topography is especially well developed in Section 14, southern Section 7, and southwestern Section 8, where the knolls rise 40 feet or more. In southwestern Section 7, a few small kame-like knolls 20 feet high are made up in large part of dirty, poorly sorted, subangular gravel in which till masses are included. At the Illinoian boundary in the northwestern central part of Section 8, well developed kames from 30 to 50 feet high cover an area of about one-fourth square mile (Fig. 2), choking a pre-Illinoian valley and causing a minor stream diversion.

Other Areas in Knox County.—Well developed constructional topography, consisting of rounded knolls 20 to 30 feet in height banked against the valley sides, exists in a small area of about one square mile along the northeast side of the valley of Schenck Creek in northeastern Monroe Township. The area extends

northward for a little more than a mile up the valley of Coleman Branch and northwestward to the mouth of Little Schenck Creek. Cobbly gravel is present on either side of Coleman Branch about one-half mile north of its junction with Schenck Creek. The till of the northern part of this area is very bouldery as is the till of the ground moraine farther northward.

An oval shaped area of rounded drift knolls, one-half mile long and one-quarter mile wide, is crossed by Little Jelloway Creek just south of the Brown Township line in northwestern Howard Township. About a mile to the north is a slightly smaller moraine area in central Section 24, Brown Township. It rises about 40 feet above the valley floor. Little Jelloway Creek detours around it through the hills, the stream returning to its old valley one-half mile south of the till dam. The surface is undulating to hummocky and quite constructional in appearance.

The Davis Basin.—This is a rectangular area about three miles northeast of Butler, covering about three square miles in Sections 13, southern 12, eastern 14, and southeastern 11 in eastern Worthington Township, Richland County, just west of the Ashland County line. The name, not on the map, is derived from the tiny hamlet formerly known as "Davis Post Office" at the crossroad on the line between sections 12 and 13. The surface is gently undulating rather than hummocky, except in the northeastern Section 14, where rather smooth, gravelly knolls 10 to 20 feet high are present. The floor of the basin rises from an elevation of 1,220 feet in the central part to about 1,300 feet at the borders. The basin is bounded on the east by unglaciated bedrock hills, on the south and west by bedrock hills on which glacial deposits are very meager, and on the north by Wisconsin moraine. The material is silty till, except for the gravel knolls in Section 14, and for a small area of dirty gravel in central Section 13. Till continues to within 200 yards of the glacial boundary, just west of the county line.

Northeastern Jefferson Township, Richland County.—Drift with fairly definite constructional topography partly fills the valley of a small southward flowing tributary to Clear Fork in central Section 11 and central southern Section 2. Pronounced drift knolls are banked against the hillside just north of the road forks at the line between the two sections (Fig. 4). The till is quite variable in this small area, ranging from silty, through sandy, to gravelly clay. Brown, leached, pebbly till

is exposed in a cut 12 feet deep along a road just northeast of the road forks. The pebbles are so greatly weathered that many of them break with a light blow of the hammer.

AREAS OF KAME TOPOGRAPHY

Small areas of kame-like hills are associated with the larger areas of morainal topography at several places in western Knox County and have already been mentioned. Kame-like knolls, aggregated in the form of kame terraces, are also present at two places in the Kokosing valley. These benches made by kames that rise to a general level are quite similar to the more extensive Wisconsin kame terraces in valleys in the Allegheny Plateau (4, 5), and are believed to be remnants of Illinoian kame terraces.

An area of kames nearly one-half square mile in extent exists about one mile west of Millwood in eastern Howard Township along the north side of the Kokosing valley. Gravel hills are banked against the valley wall, making a rude terrace bench that rises to an elevation of 1,040 feet, although mostly below 1,000 feet. The gravel is variable in texture, ranging from medium-grained to cobbly, and apparently includes some till masses. To the north the gravel grades into gravelly till which conceals the bedrock up to an elevation of 1,100 feet.

Two miles east of Gambier, on the south side of the Kokosing valley just north of Arbutus Glen, is another area of kames about one-quarter square mile in extent. The area is within the valley but rises nearly 80 feet above the flood plain of the river, making a terrace-like feature. The surface is strongly undulating rather than with knobs, suggesting kame and kettle topography that has been modified by erosion, the kames being subdued, the kettle holes reduced and breached. Cobbles of resistant rocks are common on the surface. This undulating and irregular surface is very poorly delineated on the Gambier topographic sheet.

VALLEY TRAIN REMNANTS

Outwash gravels must have been laid down in valleys, beyond and within the Illinoian drift region, but they have been so completely removed by later erosion that only a few remnants remain. Only one fairly extensive group of terrace remnants and two isolated remnants have been noted.

Clear Fork Valley.—Remnants of an Illinoian terrace are preserved over a distance of two and one-half miles on the north side of Clear Fork valley at Bellville, Richland County. These remnants are about 60 feet above the continuous lower Wisconsin valley train at Bellville. One small remnant of the higher terrace remains on the south side of the valley.

The remnant of the Illinoian terrace farthest upstream is immediately north of Bellville at an elevation of 1,200 to 1,220 feet, just east of the Wisconsin boundary. One-half mile east of the village, a larger remnant one-third mile long is preserved. It is flat-topped, has an elevation of 1,190 feet, and partly closes a tributary valley from the north. One-quarter mile southeast of the village another small remnant has an elevation of 1,190 feet, and one-half mile farther east, in southern Section 11, a larger remnant about one-half mile long has an elevation of about 1,180 feet. Farther downstream no evidence of Illinoian terrace remnants was noted.

That these remnants of the higher terrace are Illinoian and not a high Wisconsin terrace is shown by several lines of evidence. First, the elevation of the top of the Wisconsin end-moraine at Bellville is 1,180 feet. The well marked valley train extending down valley from it has an altitude of 1,144 feet in Bellville. The remnants of the higher terrace are therefore above the possible reach of Wisconsin waters. Further, the surface of the higher terrace is much more eroded than the surface of the lower terraces. Finally, the mineral grains separated from the soil on top of the higher remnants show the degree of alteration characteristic of Illinoian drift deposits (6).

The remnants represent a valley train that was at least three miles long, and probably much longer, deposited from the Illinoian ice after it had retreated more than eight miles west of its farthest eastward position. These remnants indicate definitely, however, that in the vicinity of Bellville, the valley of Clear Fork was filled, during the waning of the Illinoian ice, to an elevation from 60 to 80 feet higher than the present stream level. All remnants have been completely removed downstream from a point two and one-half miles east of Bellville and Wisconsin glaciation has obliterated any remnants that may have been preserved west of Bellville. It is impossible, therefore, to determine where the valley train headed or how far downstream it extended.

Mohican Valley.—A small bench area about one-half mile long and 100 feet above the Wisconsin terraces exists on the inside of a great bend on the east side of the Mohican River at the Knox-Coshocton county line, one mile southwest of Cavallo. It extends from central eastern Section 20, Union Township, Knox County, eastward into Tiverton Township, Coshocton County, and is crossed by the road along the east side of the Mohican valley. The elevation of this bench is a little over 1,000 feet and the elevation of the Wisconsin terrace below is a little over 900 feet. There are no good exposures of the material, but cobbles are prominent on the surface. These cobbles are more weathered than those of the Wisconsin terrace below. This bench, one mile east of the mapped Illinoian boundary, may be a remnant of local outwash deposited before the present course of the Mohican River was established by the meltwater from the ice.

A small, ridge-like remnant of Illinoian outwash is present in the Walhonding valley, three-fourths mile east of the Mohican River, just northwest of Walhonding village. This remnant is one-quarter mile long and one-eighth mile wide. Its top is considerably dissected, but small, flat-topped areas remain at an elevation of 940 to 960 feet. It is separated from bedrock hills to the north by a small, open valley, one-quarter mile wide. The Illinoian outwash is overlapped to the east and south by an extensive Wisconsin outwash terrace having an elevation of 880 to 900 feet. The Illinoian gravel ridge apparently continues to the northwest, but actually, the ridge to the northwest, above an elevation of 960 feet, is of Mississippian bedrock. The Illinoian gravel is not exposed in any pits, but from surface indications it seems to be medium to coarse-grained, with a few cobbles up to six inches in diameter.

ACKNOWLEDGMENTS

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REFERENCES

(1) **Leighton, M. M.,** and **MacClintock, Paul.** Weathered Zones of the Drift-Sheets of Illinois: *Jour. Geol.*, Vol. 38, pp. 28–53, 1930.
(2) **Leverett, Frank.** Glacial Formations and Drainage Features of the Erie and Ohio Basins: *U. S. Geol. Surv. Mono. 41*, 1902.
(3) **MacClintock, Paul.** Physiographic Divisions of the Area Covered by the Illinoian Drift-Sheet in Southern Illinois: *Report of Investigations, No. 19, State Geol. Surv. Ill.*, pp. 7–26, 1929.
(4) **White, G. W.** Glaciation of Northwestern Holmes County, Ohio: *Ohio Jour. Science*, Vol. 31, pp. 429–453, 1931.
(5) ———. An Area of Glacier Stagnation in Ohio: *Jour. Geol.*, Vol. 40, pp. 238–258, 1932.
(6) ———. Soil Minerals as a Check on the Location of the Wisconsin-Illinoian Drift Boundary in North Central Ohio: *Science*, Vol. 79, pp. 549–550, 1934.
(7) ———. The Pleistocene Geology of the Region of the Reentrant Angle in the Glacial Boundary in North Central Ohio: *Abstracts of Doctors' Dissertations, No. 13*,, pp. 282–293, Ohio State Univ. Press, 1934.
(8) ———. Drainage History of North Central Ohio: *Ohio Jour. Science*, Vol. 34, pp. 365–382, 1934.
(9) ———. The Powell and Broadway End Moraines: *Am. Jour. Science*, Vol. 30, pp. 33–44, 1935.

Nuclear Physics

The rapid development of this branch of physics, together with the great popular interest it has aroused renders a work on this subject a matter of prime importance. The present volume is essentially an English edition of the Italian work of this young co-worker of Fermi (F. Rasetti, Il Nucleo Atomico, Zanichelli, Bologna, 1936).

But any subject which is in a state of rapid transition always lays itself open to the possibility that by the time it is published much of the material that it contains will be obsolete. This criticism applies to this work to a limited extent, although it contains references only three months old. It is valuable to the experimental physicist in its wealth of tables and charts, which to a large degree will probably stand the test of time.

Experimental methods are fully discussed, and in a few cases, brief theoretical discussions are given, but these are, in the main, somewhat sketchy and too advanced for beginning students.

The first half of the book is concerned with an introduction and historical study of the interaction of matter and radiation, including a very fine summary of natural radioactivity. There follows a general study of nuclear structure, including properties derived from other fields of study (principally spectroscopy). The last hundred pages are devoted to artificial disintegration and induced radioactivity and cosmic rays. This is the author's own special field, and is especially well written and up-to-date including mass of nuclei as derived from disintegration processes.

This book is the second volume of the new Prentice-Hall Physics Series edited by E. U. Condon. It is well printed on very fine paper and quite substantially bound.—J. B. Green.

Elements of Nuclear Physics, by F. R. Rasetti. xiv+327 pp. New York, Prentice-Hall, Inc., 1936. $4.50.

MORPHOLOGY OF THE FORELIMB OF THE MOLE (SCALOPS AQUATICUS, L.) IN RELATION TO ITS FOSSORIAL HABITS

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INTRODUCTION

The common American mole (*Scalops aquaticus*, Linnaeus) is a completely fossorial animal which spends its entire existence in underground tunnels of its own construction. The fossorial adaptations which enable the mole to lead its subterranean mode of existence have been described, at least in a general way, by numerous authors. The most comprehensive description of the morphology of the mole is the work of Dobson ('82), whose description, however, concerns primarily the European mole (*Talpa europea*) and the star-nosed mole (*Condylura cristata*), although frequent references are made to other species including *Scalops aquaticus*. Slonaker ('20), in addition to summarizing the results of former investigators which, as he pointed out, are more or less fragmentary and scattered promiscuously throughout the literature, also described certain adaptive modifications in the American mole, particularly the osteology of the forelimb and pelvis and correlated these with the animal's habits and environment.

The objectives aimed at in the present paper are threefold, namely: (1) a more detailed description of the osteology of the forelimb of the mole than has heretofore been given; (2) a description of the articulations of the forelimb, including articular surfaces involved, ligaments with their attachments and adaptive modifications, the normal position assumed by each segment of the forelimb and the kinds of movements permitted at the various joints; and (3) a description of the musculature including the arrangement, attachments (origins and insertions), actions and nerve supply of the muscles, with the view to correlating these features with the peculiar functions which the forelimb performs in the process of constructing the underground tunnels.

The mole is especially adapted to a life spent entirely beneath the surface of the ground in burrows where it secures not only

shelter but also its food. Its neck appears to be so short that it is almost imperceptible. However, the shortness of the neck is more apparent than real and is due to the fact that the forelimb has shifted forward rather than to an actual shortening of the cervical region of the vertebral column, since this region contains the characteristic number of vertebrae typical of the mammals, namely, seven. The forward shift of the forelimb is the result of the pre-sternum or manubrium having elongated into a keel-shaped bone, to the anterior extremity of which the short clavicles articulate (fig. 1C). As a consequence, therefore, of the forelimbs having shifted forward upon the neck,

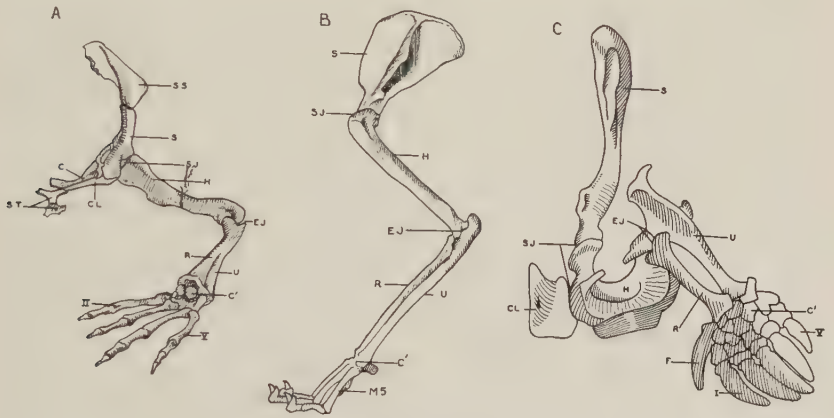

FIG. 1. A—Anterior (cranial) view of articulated forelimb of frog; B—lateral view of articulated forelimb of cat; C—anterior view of articulated forelimb of mole. These illustrations were made with disregard of relative size. (Interpretation of legends is given in list of abbreviations, page 41.)

not only is the latter apparently shortened but the shoulder-joints are brought nearer each other thus causing an apparent shortening of the forelimbs, while preserving at the same time their normal leverage. These are important fossorial adaptations which enable the mole to economize in working room, since a long neck and long, projecting forelimbs would be mechanical disadvantages to a burrowing animal working in close quarters.

The bones of the forelimb, especially the clavicle, scapula and humerus, are singularly developed and modified rendering it difficult to homologize certain of their configurations with those of other mammals. They are for the most part quite strong and exhibit prominent processes for the attachment

of the powerful muscles which serve to put the forelimbs into action.

The manus is especially modified to form an effective digging mechanism. It is not only strong and broad, but the digits are provided with strongly developed nails sharpened at their tips. Broadening of the manus has been accomplished (1) by a relative increase in the width of the bones of the manus, (2) by the development of an accessory bone, the so-called falciform bone, situated external to the pollex and (3) by the abduction (spreading apart) of the digits which are webbed throughout the greater part of their length. The position of the manus is such as to render it favorable for digging and makes it poorly adapted for progression on a hard supporting surface, as is evidenced by its awkward scraping movements when the animal attempts to scurry to safety when placed on such a surface.

Comparison of the articulated forelimb of the mole when at rest with that of typical tetrapod mammals reveals that the position of its segments has been greatly altered to meet the demands placed upon it. In the more primitive tetrapods, as for example, the amphibians (fig. 1A), the brachium is abducted, that is directed almost horizontally outward at right angles to the longitudinal axis of the body such that the elbow-joint projects laterad; the antibrachium is semi-flexed and semi-pronated and the manus is slightly extended at the wrist-joint so that the palm rests upon the ground. In the typical forelimb of mammals as in the cat for example (fig. 2B), the brachium is swung backward (flexed) and adducted so that the elbow-joint lies close to the side of the body and is directed caudad; the antibrachium is semi-flexed and semi-pronated and the manus is extended at the wrist-joint. As regard the normal position of the tetrapod shoulder-girdle the scapula which, unlike the clavicle, is constant in occurrence, is a flat, triangular bone applied against the lateral aspect of the thorax in an oblique direction, such that its glenoid cavity is directed ventrad and more or less craniad, its superior or vertebral border dorsad and somewhat caudad.

In the forelimb of the mole (fig. 3C) the brachium has assumed a more abducted position than that of the amphibians and in addition has swung forward (extended) in such a manner that the elbow-joint is directed antero-laterad. Moreover the antibrachium is apparently so greatly pronated that the palm

of the manus faces postero-laterad. The apparent extreme pronation of the antibrachium is the result of the humerus having undergone considerable medial rotation, as is evident by the spiral course of the nerves to the forelimb (figs. 14, 15), and of the head of the humerus having shifted to its dorsal surface so that its neck and shaft form an angle of about 90°, rather than actual pronation of the antibrachium as is evident from the position of the radius and ulna with respect to each other (fig. 3C).

As a result of the torsion undergone by the humerus its proper lateral border faces antero-mediad and its medial border postero-laterad, while, as a result of extension and abduction, its proximal extremity is directed postero-mediad and its distal extremity antero-laterad. That the radius and ulna have not actually undergone much pronation is evidenced by the fact that they lie parallel with each other and are uncrossed. Moreover, the ulna is situated in a position lateral to that of the radius, a very unusual position due to the torsion of the humerus, while the proper dorsal surface of both radius and ulna faces antero-laterad thus resulting in the radial border of the manus facing postero-laterad and its ulnar border antero-mediad, such that the pollex points ventrad and caudad and the palm faces laterad and caudad. A simulation of the peculiar position assumed by the forelimb of the mole may be gained in the superior extremity of man by performing the following movements: swinging forward and abduction of the brachium at the shoulder-joint to a ninety-degree angle; semiflexion of the antibrachium at the elbow-joint and extreme medial rotation of both the brachium and antibrachium.

Concomitant with the favorable position assumed by the free forelimb of the mole in its burrowing habits are the peculiar morphological modifications and position of the bones of the shoulder-girdle. When the mole is engaged in excavating its burrow considerable lateral pressure is exerted upon the forelimb—hence the importance of a powerful shoulder-girdle to resist the great muscular strain. The clavicle, unlike that of other mammals in which it is present, articulates with the humerus, but not with the scapula. It is so constructed and situated as to resist this lateral pressure and to furnish a strong and stable fulcrum upon which the humeral lever swings.

The scapula exhibits remarkable morphological adaptations in its shape as well as its position. In conformity with the

change in position of the humerus as well as its head the shape and position of the scapula have likewise been altered. Thus it has undergone a posterior rotation so that its proper dorsal border is directed caudad, its anterior border dorsad, its posterior border ventrad and the glenoid cavity craniad. Moreover, as a consequence of the humerus having shifted forward due to the forward extension of the manubrium, the scapula has become greatly elongated and has come to lie along the side of the neck and dorsal to the first five or six ribs.

OSTEOLOGY

The **Clavicle** (figs. 1C, 4) is extraordinarily short and somewhat cuboidal in form. Its proximal or medial extremity is marked by an elliptical-shaped concavity which articulates with a reciprocal-shaped convexity on the anterior extremity of the presternum or manubrium. Its distal or lateral extremity presents an oval shaped, concave articular surface for articulation with a similar shaped convex articular surface (clavicular facet) on the greater tuberosity of the humerus (figs. 1C, 5, 6). Its anterior surface is smooth and gives origin to the deltoid muscle (fig. 12). Extending from the anterior to the posterior surface is a foramen which transmits a blood-vessel. On the ventral border is a slight projection, the subclavian tubercle, into which the subclavius muscle (fig. 12) is inserted. Into the posterior aspect of the lateral extremity is inserted the pectoralis minor muscle (fig. 12) and to its superior aspect is attached the acromioclavicular ligament (fig. 15).

The **Scapula** (figs. 1C, 2, 3) is remarkably slender and elongated. Its posterior (original dorsal or vertebral) border is short, rounded and roughened for the attachment of muscles, namely, the trapezius anterior, rhomboids, levator scapulae and serratus (magnus) anterior muscles (fig. 13). Its medial or costal surface presents a slight elongated depression, the subscapular fossa, from which the subscapularis muscle (fig. 15) arises. Its lateral or external surface presents numerous bony configurations; one of these, the spine, into which the trapezius posterior (fig. 13) inserts, is but slightly developed; the supraspinous fossa is narrow, shallow and elongated and furnishes the origin for the supraspinatus muscle (fig. 15); the infraspinous fossa is deeper and marks the point of origin of the infraspinatus muscle (fig. 15). The latter fossa is bounded above and below by ridges, the lower giving rise to the teres minor muscle (fig. 15) and to the long or scapular head of the triceps muscle (figs. 13–15).

A coracoid process is not in evidence. However, the acromion process is well marked and somewhat roughened for the attachment of the acromioclavicular ligament.

The ventral (original posterior) border of the scapula is rounded and gives origin to the teres major muscle (figs. 13–15). The glenoid fossa, which receives the head of the humerus, is shallow and elongated transversely. Near it on the ventral border is a slight projection, the infraglenoid tubercle, from which the biceps brachii muscle (figs. 12, 15) arises.

The **Humerus** (figs. 1C, 5, 6) is most unusual in shape and is characterized by its shortness, the great development of its processes for muscular attachments and by the presence of an articular surface (clavicular facet) for articulation with the clavicle. The head is elongated transversely and projects posteriorly. The neck, into which the supraspinatus muscle inserts, forms an angle with the shaft of about 90°.

The proximal extremity is marked by the peculiarly shaped tuberosities. The greater (external) tuberosity presents a large oval shaped articular facet (clavicular facet) for the lateral extremity of the clavicle and a sharp spinous process which projects distally. From the posterior aspect of the former arises the deep portion of the external head of the triceps (fig. 14) and into it is inserted the infraspinatus muscle. From the spinous process arises the superficial portion of the external head of the triceps and into it inserts the teres minor muscle (fig. 15). The greater tuberosity overhangs a deep fossa which extends upward under the clavicular facet and is continuous on the lateral border with a spiral groove. This fossa and groove, which curves forward to the ventral surface, give origin to the brachialis muscle (figs. 12, 15).

The lesser (internal) tuberosity consists of two laminae of bone which fuse to form the so-called bicipital ridge and the intertubercular (bicipital) groove. Into the ridge are inserted the subscapularis muscle (fig. 15) and the posterior superficial and deep portions of the pectoralis major muscle (figs. 12, 15). The groove is peculiar in that it is transformed into a closed canal for the passage of the long, slender tendon of origin of the biceps muscle (fig. 15). Distal to these laminae is a notch, which separates them from a crest-like process (L3) into which is inserted the conjoined tendon of the latissimus dorsi and teres major muscles (figs. 12, 15). The tendon of origin of the biceps passes through this notch to gain the ventral surface of the humerus.

The ventral surface presents proximally a large, smooth triangular surface bounded externally by the deltoid tuberosity and internally by the pectoral ridge. Into the former inserts the deltoid muscle and into the latter are inserted the anterior superficial and deep portions of the pectoralis major muscle (figs. 12, 15). The dorsal surface is marked by a pronounced, obliquely situated, groove from which the internal head of the triceps muscle (figs. 12, 13, 15) arises.

The distal extremity presents a number of processes, two of which are articular for the bones of the antibrachium, while the others serve for muscular attachments. The lateral epicondyle consists of a sharp spinous process which gives origin to the anconeus externus muscle (fig. 14) and the dorsal or extensor group of muscles of the antibrachium (figs, 13, 15). Just internal to this is the smooth, oval shaped capitulum for articulation with the proximal extremity of the radius and above the capitulum is a slight depression, the radial fossa, for the reception of the margin of the sigmoid cavity on the proximal end of the radius during extreme flexion of the elbow-joint.

The medial epicondyle is marked by a spinous process proximally and a facet-like process distally. From the former arise the anconeus internus, pronator teres and palmaris longus muscles, while to the

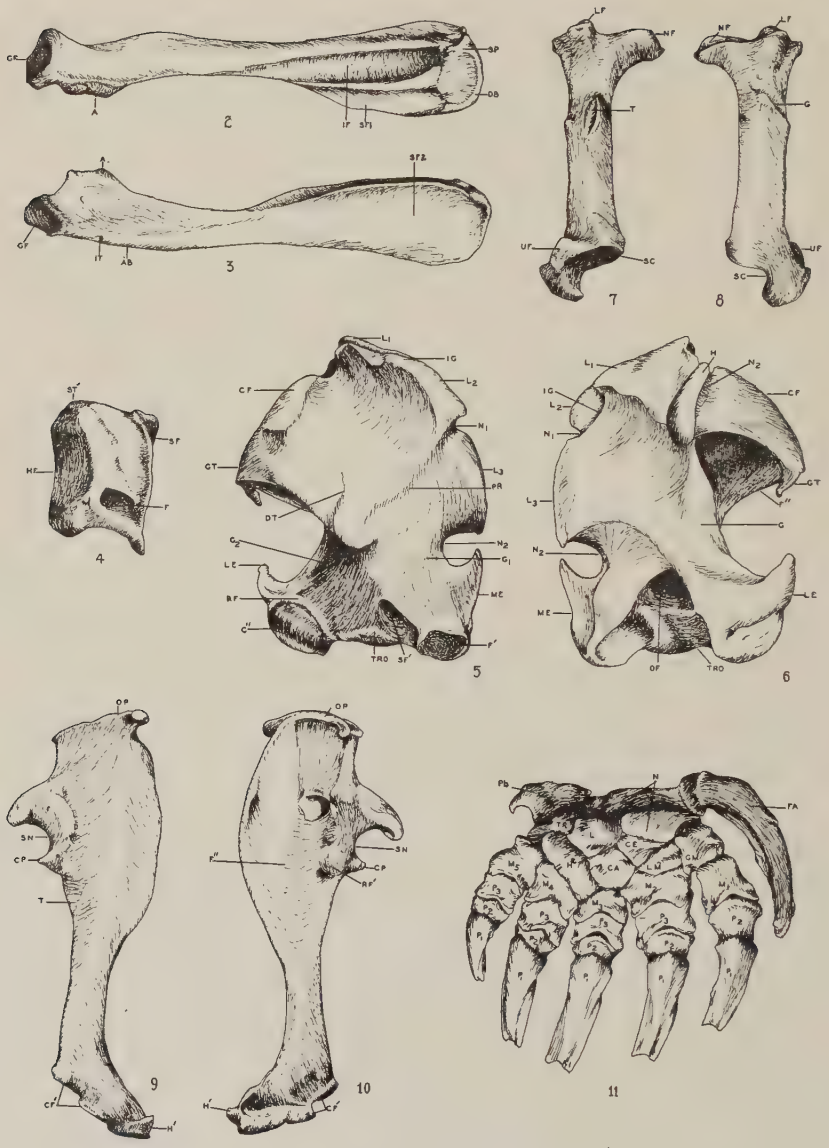

FIG. 2. Lateral aspect of right scapula of mole.
FIG. 3. Medial aspect of right scapula of mole.
FIG. 4. Anterior (cranial) aspect of right clavicle of mole.
FIG. 5. Ventral (original anterior) aspect of right humerus of mole.
FIG. 6. Dorsal (original posterior) aspect of right humerus of mole.
FIG. 7. Ulnar (original medial) aspect of right radius of mole.
FIG. 8. Medial (original lateral) aspect of right radius of mole.
FIG. 9. Lateral (original medial) aspect of right ulna of mole.
FIG. 10. Medial or radial (original lateral) aspect of right ulna of mole.
FIG. 11. Dorsum of right articulated manus of mole.

(Interpretation of legends is given in list of abbreviations, page 41.)

latter is attached the tendinous flexor digitorum profundus (fig. 14). Adjacent to the medial epicondyle on the ventral surface are the supracondylar foramen, which transmits the median nerve, and a slight coronoid fossa for the reception of the coronoid process of the ulna (fig. 10) during extreme flexion of the elbow-joint, while on the dorsal surface is the deep olecranon fossa for the reception of the posterior margin of the semilunar notch of the ulna during extreme extension of the elbow-joint.

The **Radius** (figs. 1C, 7, 8) is also greatly modified. Thus its proximal extremity presents a sigmoid cavity for articulation with the capitulum of the humerus rather than a circular disc or head as in most higher forms. On its medial aspect is a small articular facet for articulation with a corresponding facet on the adjacent margin of the proximal extremity of the ulna. The medial surface of the shaft is roughened, forming what may be termed the bicipital tuberosity for the insertion of the biceps brachii muscle (figs. 12, 15), near which is the point of insertion of the pronator teres muscle (fig. 14). The lateral surface presents an obliquely directed groove through which the tendon of the extensor ossi metacarpi muscle (fig. 15) glides. The distal extremity is greatly expanded from lateral to medial and bears two articular surfaces, a lateral one for articulation with the navicular (scaphoid) bone and a medial one for articulation with the lunate (semilunar) bone. Little or no articulation occurs between this extremity of the radius and that of the ulna.

The **Ulna** (figs. 1C, 9, 10) exhibits still greater fossorial adaptations. Its proximal extremity is marked by a greatly pronounced olecranon process which is expanded at its free end and is keeled throughout its length, as a result of which leverage of the extensor muscles of the elbow-joint is greatly increased. Into this process are inserted the anconeus externus and internus (figs. 14, 15) and the triceps (figs. 14, 15) muscles, while it serves for the point of origin of the flexor (fig. 14) and extensor (fig. 13) carpi ulnares, the flexor digitorum sublimis (fig. 14), the extensor pollicis et indicis (fig. 15) and the extensor ossi metacarpi (fig. 15) muscles. The semilunar notch is so deep and narrow that it almost approximates a hollow cylindrical articular surface which tends to increase the stability of the elbow-joint. It is bounded proximally by a hook-like process of the olecranon and distally by the coronoid process. Just distal to the latter on the volar (anterior) surface is a roughened area, the ulnar tuberosity, into which the brachialis muscle (fig. 15) is inserted. As mentioned above, on the lateral margin of the semilunar notch is a small articular facet for articulation with a corresponding one on the medial margin of the sigmoid cavity of the radius. The distal extremity presents laterally a notched articular surface, which articulates with the triquetral (cuneiform) bone, and medially a hook-like articular surface, which articulates with the pisiform bone.

The **Manus** (figs. 1C, 11) is composed of the typical divisions, namely, the carpus, metacarpus and digits. The carpus consists of two rows of bones, a proximal row containing the navicular (scaphoid), lunate (semilunar), triquetral (cuneiform) and pisiform, and a distal row containing the greater multangular (trapezium), lesser multangular

(trapezoid), the central (centrale or intermedium), the capitate (os magnum) and hamate (unciform). The palmar aspect of the carpus is smooth and is bounded laterally by a ridge on the navicular bone and medially by the pisiform bone, thus forming a somewhat shallow groove for the passage of the tendons of the volar or flexor group of antibrachial muscles.

The metacarpal bones are five in number and quite short. They are somewhat wedge-shaped with their palmar surfaces reduced to narrow transverse crests in which are grooves for the tendons of the flexor digitorum profundus muscle. The phalanges are short, broad and flattened, with the typical number present. The distal or terminal phalanges are bifid and provided with long, broad nails sharpened at their tips. The falciform bone lies to the lateral side of the pollex and is attached proximally to the navicular bone while its distal free extremity extends to the base of the proximal phalanx of the pollex.

ARTICULATIONS

The **Sternoclavicular-joint** is surrounded by an articular capsule which is reinforced dorsally and ventrally by accessory ligaments. An articular disc is not present as in man. The movements permitted at this joint are protraction (swinging forward) and retraction (swinging backward) of the clavicle.

The **Shoulder-joint** (fig. 3C) is a double one, being composed of a humero-scapular and a humero-clavicular element. Since the humerus typically articulates only with the scapular element of the shoulder-girdle, it is apparent that the significance of this double articulation in the mole is that it adds stability and serves to produce a firm support for the humerus to swing upon as a lever during the digging movements. The clavicle of the mole therefore does not serve as a prop to support the scapula as in man, but rather as a fulcrum on which the humerus swings.

The ligaments involved in this articulation are two articular capsules, one for each part of the joint. These are reinforced dorsally and ventrally by accessory bands of fibers. In addition the strong acromioclavicular ligament (fig. 15) adds further strength and security. It is attached to the acromion of the scapula and to the dorsal aspect of the lateral end of the clavicle. The attachments and size of this ligament would seem to indicate that it serves to brace the proximal end of the scapula against the lateral end of the clavicle and, therefore, compensates for the lack of an articulation between these bones.

Due to the nature of the articular surfaces composing the shoulder-joint it is probable that the movements permitted at the humero-clavicular portion are swinging forward (extension) swinging backward (flexion), elevation sideward (abduction) and depression to the side (adduction), whereas it is possible that only abduction and adduction occur at the humero-scapular portion. It is doubtful whether rotation of the humerus takes place at either of these points, since the nature of the articular surfaces and arrangement of the ligaments, especially the acromioclavicular, would seem to render this movement impossible.

The **Elbow-joint** (fig. 3C) is likewise a double articulation, consisting of humero-ulnar and humero-radial elements. As a result of the nature of the articular surfaces involved great strength and security are obtained here. In addition to the articular capsule, with which each

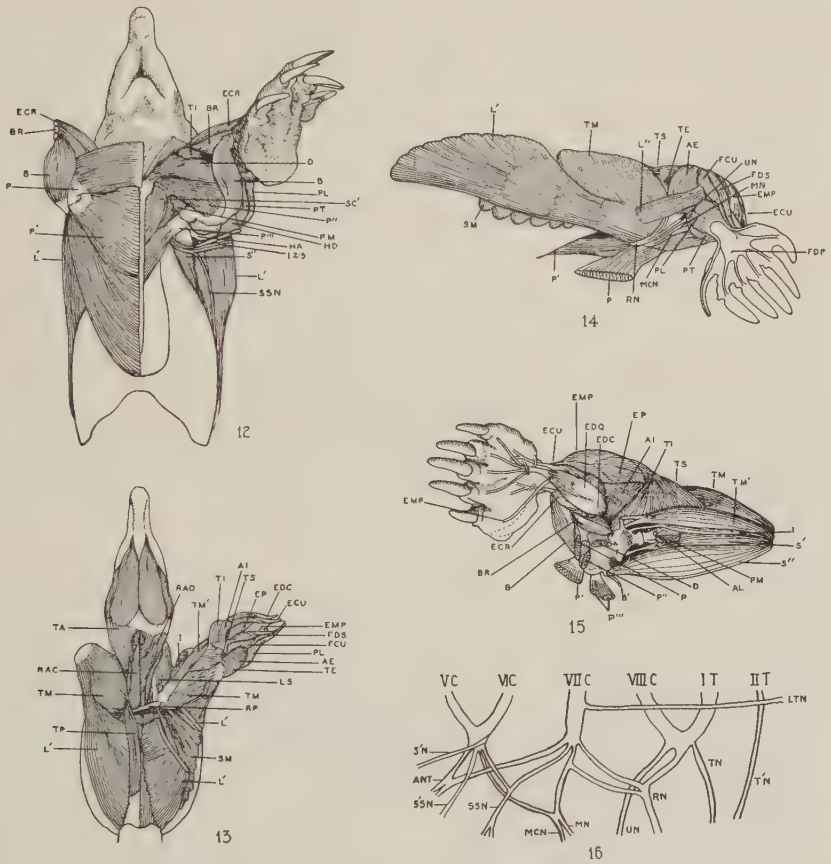

FIG. 12. Ventral aspect of muscles of forelimb of mole.
FIG. 13. Dorsal aspect of muscles of forelimb of mole.
FIG. 14. Lateral aspect of muscles of right forelimb of mole.
FIG. 15. Medial aspects of muscles of right forelimb of mole.
FIG. 16. Diagram of left brachial plexus of mole, showing the origin of only the nerves to the muscles of the forelimb.

(Interpretation of legends is given in list of abbreviations, page 41.)

element is provided, accessory ligaments are present. These extend from the margin of the sigmoid cavity of the radius to the lateral epicondyle and adjacent margin of the semilunar notch of the ulna and from the latter to the medial epicondyle. The movements which occur are limited to flexion and extension.

Although the proximal extremities of the radius and ulna articulate, forming what may be termed a superior radio-ulnar articulation, it is doubtful whether any pronation or supination occur here.

The **Wrist-joint** (fig. 3C) is also a double articulation. It consists of two facets on the distal extremity of the radius, which articulate with the navicular and lunate bones, and articular surfaces on the distal extremity of the ulna, which articulate with the triquetral and pisiform bones. According to Dobson (loc. cit., p. 164) the pisiform bone does not enter into the wrist-joint. However, in Scalops aquaticus this is a well defined articulation and the articular surfaces are of such a nature as to form somewhat of an interlocking device thus adding security to the joint, and permits only flexion and extension. It is provided with an articular capsule which is reinforced by means of short, strong ligaments.

An inferior radio-ulnar articulation does not occur, although ligaments connect the distal extremities of the radius and ulna.

In the remaining articulations of the manus flexion and extension occur freely, the digits maintaining a position of abduction, that is spread apart. Moreover, the normal position of the digits when the mole is at rest is extension rather than slight flexion as in man thus giving the manus its shovel-like appearance. The base of the falciform bone is held firmly against the lateral side of the navicular bone by means of short, strong ligaments. It is attached throughout most of its length to the side of the pollex by a fold of skin.

MUSCULATURE

The origin, insertion and nerve supply of the muscles of the forelimb were observed by means of dissection, whereas their actions were determined by applying the principles of leverage, that is, by noting their points of attachment on the articulated limb, by pulling upon the dissected muscles and observing the resulting movements. Observations were made on the movements of the living animal, although these yielded unsatisfactory results as regard primary muscle action. However, the fundamental movements of the various segments of the forelimb during the digging process were thereby ascertained. Naturally, the question arises as to the homology of these muscles with those of higher mammals. Notwithstanding the difficulties encountered due to the numerous modifications and morphological adaptations exhibited by the majority of these muscles, this was, for the most part, readily determined by employing the criteria of nerve supply and morphology, including points of attachment. However, in a few instances, notably the pectoralis minor and subclavius muscles, their homology is questionable and the writer may be in error in employing these names. As regard the subclavius Dobson observed and described it as such for the star-nosed mole, whereas he made no mention of the muscle described in this paper as the pectoralis minor but applied this name to the posterior deep portion of the pectoralis major, with which it is generally conceded to be homologous.

In addition to the proper appendicular muscles of the fore-limb

there are two cutaneous muscles attached to the humerus, namely, the humero-dorsalis and humero-abdominalis. These are portions of the cutaneous maximum or panniculus carnosus which serves primarily to move the integument. However, since these two muscles are attached to the humerus (origin) and to the skin of the back and abdomen (insertion) their action may be reversible, that is they may serve to move the humerus.

The **Humero-dorsalis** (fig. 12) arises from the shaft of the humerus under cover of the biceps brachii muscle and inserts into the skin on the sides of the back. It may serve indirectly to flex the humerus, that is, draw it backward.

The **Humero-abdominalis** (fig. 12) arises from the bicipital ridge of the humerus under cover of the insertion of the posterior superficial pectoralis major and inserts into the skin on the sides of the abdomen. It may likewise serve to flex the humerus.

The **Pectoralis major** (figs. 12, 14, 15) is a large, complex muscle which extends from the ventral aspect of the thorax to the humerus. It is divisible into four parts, two of which are superficial and two deep. The anterior superficial pectoralis (pars clavicularis of man) (P) arises from the anterior end of the manubrium and from a raphè craniad to it and inserts into the pectoral ridge of the humerus. This raphè forms a common tendon of origin for both anterior superficial pectorals thus providing a continuous band stretching across between both forelimbs and serving to hold them in position. The posterior superficial pectoralis (pars sternocostalis of man) (P′) takes origin from the entire length of the sternum and is inserted into the bicipital ridge of the humerus. The anterior deep pectoralis (pars prescapularis; pectoralis parvus) (P″) arises from the anterior surface of the clavicle and inserts into the pectoral ridge of the humerus. The posterior deep pectoralis (pectoralis minor of man) (P′ ″) arises from the manubrium and costal cartilages and inserts into the bicipital ridge of the humerus. The action of the pectoralis major as a whole is to adduct the humerus. Its separate divisions when acting as functional units perform the following movements: the anterior superficial and deep portions pull the humerus forward while the posterior superficial and deep portions pull it backward.

The **Subclavius** muscle (fig. 12) is situated deep to the pectoralis major where it arises from the side of the manubrium and the first few costal cartilages. It passes forward to be inserted into the subclavian tubercle of the clavicle. It retracts the clavicle, that is, pulls it backward, and like its homologue (?) in man subserves the function of bracing the clavicle against the manubrium.

The **Pectoralis minor** muscle (figs. 12, 15) lies deep to the subclavius. It takes origin from the manubrium and is inserted into the posterior aspect of the lateral end of the clavicle, the acromioclavicular ligament and the acromion of the scapula. It retracts the shoulder-girdle. As mentioned previously the homology of this muscle is questionable. The writer ventures the suggestion that it may represent a muscle occasionally appearing in man and described in Quain's Anatomy

('23, p. 104) as the sterno- or chondroscapularis (subclavius posticus), which is said to arise from the manubrium and first costal cartilage and after passing behind the clavicle and normal subclavius to be inserted into the superior border of the scapula.

The **Trapezius** muscle (fig. 13) consists of two portions, anterior and posterior. The anterior trapezius (cranial part of human trapezius) arises from the occipital bone and inserts into the posterior border of the scapula. The posterior trapezius (caudal part of human trapezius) arise from the pelvic and sacral bones and inserts into the spine of the scapula. The anterior trapezius serves to pull the scapula forward and the posterior trapezius to draw it backward.

The **Rhomboideus** muscle (fig. 13) is also divisible into two portions, namely, anterior and posterior. The rhomboideus anterior is in turn divisible into cervical and occipital portions. The cervical portion (RAC) arises from the ligamentum nuchae, which is here ossified, and inserts into the posterior border of the scapula. It serves to draw the scapula forward (protract) and medial (adduct). The occipital portion lies partly under cover of the anterior trapezius. It takes origin from the occipital bone and is inserted into the ligamentum nuchae. It acts as a brace for the ligamentum nuchae thereby giving it support for the action of the cervical portion. The rhomboideus posterior arises from a common tendon, in conjunction with its fellow of the opposite side, which is attached to the last cervical and first thoracic vertebrae. Insertion is into the posterior border of the scapula and the action is to adduct the scapula. Moreover, with its fellow of the opposite side it serves as a ligamentous band which tends to hold the scapulae in close proximity. Dobson claims (loc. cit., p. 166) that the occipital portion of the rhomboideus anterior is "inserted into the postero-internal margin of the scapula," thus differing from the observations made by the writer.

The **Levator scapulae** muscle (fig. 13) is situated on the lateral aspect of the neck where it arises from the sides of the cervical vertebrae and inserts into the posterior border of the scapula. It protracts the scapula.

The **Serratus anterior** (magnus) muscle (figs. 13, 14) lies on the lateral aspect of the thorax where it arises by digitations from the first 8 or 9 ribs. It passes between the medial surface of the scapula and the ribs to be inserted into the posterior border of the scapula. Its chief action is to abduct the scapula, that is, pull it laterad.

The **Latissimus dorsi** muscle (figs. 12–14) is a large fan-shaped muscle situated on the side of the trunk. It takes origin from the spinous processes of the last few thoracic and all of the lumbar vetrebrae and from the dorsal surface of the sacrum. Its tendon fuses with that of the teres major muscle forming a common tendon which is inserted into the distal process (L3) on the posterior (medial) border of the humerus. The action of these muscles is to flex and abduct the humerus.

The **Tensor fasciae antibrachii** (epitrochlearis) (fig. 14) is a quadrilateral-shaped muscle arising from the tendon of the latissimus dorsi

and inserting into the antibrachial fascia and olecranon process. It serves to extend the elbow-joint and to make the fascia tense.

The **Teres major** muscle (figs. 13–15) forms a pronounced muscular mass situated on the inferolateral aspect of the scapula. It arises from the entire length of the ventral border of the scapula and inserts along with the latissimus dorsi as mentioned above.

The **Teres minor** muscle (figs. 13, 15) is a long spindle-shaped muscle situated on the lateral aspect of the scapula. It is separated from the teres major muscle by means of the long head of the triceps brachii and its tendon passes to the lateral side of the acromion and acromioclavicular ligament. It arises from the ridge which forms the lower boundary of the infraspinous fossa of the scapula and inserts into the spinous process on the greater tuberosity of the humerus. It is a weak flexor and abductor of the humerus. According to Dobson (loc. cit., p. 168) this muscle "appears to be absent."

The **Infraspinatus** muscle (figs. 13, 15) is a small spindle-shaped muscle located deep on the teres minor with which it is blended. Its origin is from the infraspinous fossa of the scapula and its insertion is into the posterior margin of the clavicular facet of the humerus. It assists in flexing and abducting the humerus.

The **Supraspinatus** muscle (fig. 15) is a long fusiform muscle which arises, as its name implies, from the supraspinous fossa and inserts into the dorso-medial aspect of the neck of the humerus. Its tendon passes medial to the acromion and acromioclavicular ligament. The action of this muscle is similar to that of the infraspinatus.

The **Subscapularis** muscle (fig. 15) occupies the entire subscapular fossa of the scapula from which it takes origin. The insertion is into the bicipital ridge of the humerus. The angle of pull is such that it must be considered a flexor and abductor of the humerus.

The **Deltoid** (figs. 12, 15) is a thin, quadrilateral-shaped muscle lying under cover of the anterior superficial portion of the pectoralis major muscle. It lies parallel with the anterior deep portion of the pectoralis major with which it is blended. Its origin is from the anterior surface of the clavicle and its insertion is into the deltoid ridge of the humerus. It serves to extend the humerus and possibly to adduct it.

The **Triceps brachii** (figs. 12–15) forms a large muscular mass on the posterior aspect of the humerus. It consists of three heads, namely, a scapular (long) head, an external head and an internal head. The scapular head (Ts) arises from the ridge forming the lower boundary of the infraspinous fossa, where it separates the teres major and minor muscles. This point of origin differs from that in typical mammals in which it arises from the ingraglenoid tubercle along the axillary border and is explained on the basis of the shift in position of the humerus. The external (lateral) head (TE) is divisible into two parts, a superficial which arises from the spinous process on the greater tuberosity of the humerus and a deep which arises from the posterior margin of the articular (clavicular) facet on the greater tuberosity. The internal (medial) head (TI) arises from the groove on the posterior aspect of the shaft of the humerus. The tendon formed by the union

of these heads is inserted into the expanded extremity of the olecranon process of the ulna. The action of this muscle as a whole is to extend the fore-arm at the elbow-joint while the scapular head may assist indirectly in flexing the humerus at the shoulder-joint.

The **Biceps brachii** (figs. 12, 15) is a thick, fusiform muscle lying on the anterior surface of the humerus. Its tendon of origin is strong, long and rounded (B′) and is attached to the infraglenoid tubercle of the scapula. This point of attachment presents a peculiar modification since in higher mammals the tendon of origin is attached to the opposite side of the glenoid fossa, that is, to the supraglenoid tubercle. Moreover, as mentioned above, the infraglenoid tubercle in higher forms marks the point of origin of the long head of the triceps. In conformity with the change of position of the humerus, that is, from the adducted position to the abducted and medially rotated one, the point of origin of this muscle as well as that of the long head of the triceps has shifted in the mole. The tendon of the biceps undergoes a rather tortuous course, passing at first ventrally to gain entrance into the closed bicipital canal of the humerus, from which it emerges to curve forward through the notch separating the ridges on the medial border of the humerus. The muscle is inserted into the roughened area (bicipital tuberosity) on the medial surface of the shaft of the radius. As in typical mammals this muscle serves primarily to flex the antibrachium at the elbow-joint. However, unlike that in most mammals, it does not supinate this region, since little or no supination occurs. Moreover, in view of the course of its tendon of origin and of its direction of pull, it may possibly adduct the brachium.

The **Brachialis** (figs. 12, 15) forms a rounded, muscular mass which occupies the fossa under the greater tuberosity and the spiral groove on the antero-lateral surface of the humerus. Its tendon of insertion is attached to the tuberosity of the ulna. It assists the biceps in flexing the antibrachium at the elbow-joint.

The **Anconeus externus** (figs. 13, 14) is a triangular-shaped muscle which arises from the spinous process on the lateral epicondyle and tendon of the teres major muscle. It inserts into the lateral surface of the olecranon process of the ulna and assists the triceps in extending the antibrachium at the elbow-joint.

The **Anconeus internus** (figs. 13, 15) is situated on the medial aspect of the humerus where it arises from the spinous process on the medial epicondyle and inserts into the expanded tip of the olecranon process. It also assists in extending the antibrachium.

The **Pronator teres** (figs. 12, 14) is situated on the volar surface of the fore-arm between the biceps and palmaris longus. It arises from the anterior aspect of the medial epicondyle of the humerus between the styloid process and the facet, and is inserted into the medial surface of the shaft of the radius. Its chief action is to assist in flexing the antibrachium. It is doubtful whether it produces any pronation of the fore-arm, since the nature of the articulation tends to limit such a movement.

The **Palmaris longus** (figs. 12–14) forms a thick muscular mass on the volar surface of the antibrachium where it lies parallel with and

medial to the pronator teres. It arises from the styloid process of the medial epicondyle of the humerus. It gives off two tendons, one of which passes lateralward to be inserted into the palmar surface of the falciform bone, the other passes medialward to be inserted into the ulnar side of the distal phalanx of the fifth digit. It serves primarily to increase the width of the manus by abducting the falciform bone and the fifth digit, although it also acts to flex the manus and the antibrachium.

The **Flexor carpi ulnaris** (figs. 13, 14) lies medial to the palmaris longus on the volar surface of the antibrachium. It arises by fleshy fibers from the medial surface of the keeled olecranon process and inserts into the pisiform bone. It assists in flexing the manus at the wrist-joint.

The **Flexor digitorum sublimis** (figs. 13, 14) lies deep to but is larger than the flexor carpi ulnaris. It takes origin on the medial surface of the olecranon process and the shaft of the ulna. Its tendon passes laterally under that of the flexor carpi ulnaris to gain the palmar aspect of the manus where it intimately blends with the underlying tendon of the flexor digitorum profundus. It assists in flexing the manus and may indirectly assist the latter muscle in flexing the digits.

The **Flexor digitorum profundus** (fig. 14) presents a very interesting fossorial adaptation. It consists of two heads of origin, one of which is muscular and the other tendinous. Its muscular origin is from the anterior border of the shaft of the ulna, while its tendinous origin is from the facet on the medial epicondyle of the humerus. The tendinous portion is quite pronounced forming a wide, strong band which is joined obliquely by the muscular portion. It enters the palm of the manus by passing through the smooth groove formed by the proximal row of the carpal bones. Within the palm it divides into five tendinous slips which insert into the terminal phalanges of the digits. The action of this muscle is threefold, namely, to flex the manus and the digits, and to exert a ligamentous action on the manus and digits by checking over-extension, thus increasing the efficiency of the shovel-like action of the manus.

The **Extensor carpi radialis** (figs. 12, 15) is a small, fusiform muscle lying on the radial side of the dorsal surface of the antibrachium. It arises from the spinous process of the lateral epicondyle of the humerus and inserts into the bases of the second and third metacarpal bones. Its tendon is crossed by that of the extensor ossis metacarpi pollicis and is held down firmly as it passes over the carpus by a ligamentous band or annular ligament. It assists in extending the manus at the wrist-joint.

The **Extensor digitorum communis** (figs. 13, 15) forms a prominent muscular mass along the middle of the dorsal surface of the antibrachium. It arises from the spinous process of the lateral epicondyle of the humerus. It breaks up into tendons which, after passing through an annular ligament, insert into the terminal phalanges of the lateral four digits. It extends the manus and digits.

The **Extensor (minimi) digiti quinti proprius** (fig. 15) is a small fusiform muscle lying on the ulnar side of the extensor digitorum

communis with which it is intimately fused. It arises from the spinous process of the lateral epicondyle of the humerus and inserts by means of a slender tendon into the terminal phalanx of the fifth digit. It serves to extend the fifth digit and assists in extending the manus.

The **Extensor carpi ulnaris** (figs. 13–15) is a fusiform-shaped muscle lying on the ulnar side of the extensor digiti quinti. It arises by two heads, one from the lateral epicondyle of the humerus and one from the expanded tip of the olecranon process. Its tendon of insertion is attached to the distal extremity of the ulna, from which it passes forward and divides into two tendons which are attached to the bases of the fourth and fifth metacarpals. It assists in extending the manus at the wrist-joint.

The **Extensor pollicis et indicis** (figs. 13, 15) is a triangular-shaped muscle situated on the ulnar side of the extensor carpi ulnaris where it arises from the tip of the olecranon process. Its small, thin tendon passes obliquely under that of the extensor digitorum communis through the annular ligament to the dorsal surface of the hand where it divides into two tendons which insert into the terminal phalanges of the pollex and index finger, respectively. It serves, as its name implies, to extend the pollex and index finger (2nd. digit) and also indirectly the manus.

The **Extensor ossis metacarpi pollicis** (extensor pollicis brevis) (figs. 13–15) lies deep to the extensor pollicis et indicis on the ulnar side of the dorsal surface of the antibrachium. It arises by two heads, one from the lateral surface of the keeled olecranon process and shaft of the ulna, the other from the lateral surface of the radius. Its tendon passes obliquely laterad through a groove on the shaft of the radius under cover of the tendons of the extensor digitorum communis, thence it passes over the tendon of the extensor carpi radialis to the radial side of the base of the first metacarpal. It extends the manus at the wrist-joint.

No intrinsic muscles were discernible in the manus.

Nerve Supply—The muscles of the forelimb are innervated for the most part by nerves which branch from the brachial plexus, a diagram of which is shown in figure 16. The pectoralis major and minor muscles are supplied by the anterior thoracic nerves, which arise from the 5th, 6th and 7th cervical nerves and pass ventrally to enter the muscles. The humero-dorsalis and humero-abdominalis muscles are supplied by branches from the 1st and 2nd thoracic nerves which pass laterad and form a plexus on the deep surface of the muscles. The nerve which supplies the subclavius muscle arises from the 5th and 6th cervical nerves. It passes directly craniad along the supero-lateral surface of the manubrium to the posterior surface of the clavicle where it terminates in the muscle.

The levator scapulae and rhomboideus muscles receive their nerve supply from branches of the cervical plexus. These branches ascend along the cranial border of the levator scapulae, giving off twigs in their ascent, to terminate in the rhomboideus muscles. The levator scapulae is, in addition, supplied by a branch from the long (posterior) thoracic nerve, which arises from the 7th cervical nerve. It passes caudad on the surface of the seratus anterior muscle which it also

supplies. The trapezius is likewise innervated by some twigs from the cervical plexus and by the spinal accessory nerve. The latter nerve courses along the lateral margin of the trapezius anterior muscle, giving off twigs, and terminating in the trapezius posterior.

The supraspinatus, infraspinatus, teres minor and deltoid muscles are supplied by a nerve which arises from the 5th and 6th cervical nerves. This nerve probably represents the combined suprascapular and axillary nerves common to mammals. It extends laterad from its point of origin and enters the supraspinatus muscle where it gives off branches to the other muscles.

The subscapularis, latissimus dorsi and teres major muscles are supplied by the subscapular nerves (fig. 12) which arise from the 5th, 6th and 7th cervical nerves.

The biceps brachi and brachialis muscles receive their supply through the musculocutaneous nerve which takes origin from the 5th, 6th and 7th cervical nerves. This nerve is the most anterior of the four nerves (fig. 14) which curve round the lateral aspect of the axilla.

The tensor fasciae antibrachii, anconeus internus and externus, triceps brachii and the extensor muscles of the antibrachium are supplied by the radial nerve which arises from the 7th and 8th cervical and 1st thoracic nerves. It curves round the lateral boundary of the axilla where it is the most posteriorly situated of the four nerves observed at this point (fig. 14). It enters the brachium just posterior to the anconeus externus and after giving off branches to the extensor group of muscles of the brachium enters the antibrachium by curving round the spinous process of the lateral epicondyle.

The flexor group of muscles of the antibrachium are supplied by the median and ulnar nerves. The median nerve arises from the 5th, 6th and 7th cervical nerves, passes laterad just posterior to the musculocutaneous nerve (fig. 14), passes into the brachium deep to the anconeus externus and enters the antibrachium through the supracondylar foramen. It supplies all the volar antibrachial muscles with the exception of the flexor carpi ulnaris. The ulnar nerve arises from the 8th cervical and 1st thoracic nerves, runs parallel with and between the median nerve anteriorly and the radial nerve posteriorly (fig. 14) and enters the antibrachium, by curving round the spinous process of the medial epicondyle, where it supplies the flexor carpi ulnaris and sends some twigs into the flexor digitorum profundus.

DISCUSSION AND SUMMARY

The most striking morphological adaptations exhibited by the bones of the forelimb of the mole may be summarized as follows: the cuboidal form of the clavicle and its articulation with the humerus rather than with the scapula; the elongation of the scapula; the broadening of the humerus, the pronounced development of its processes for muscular attachments, the closure of its intertubercular groove, the presence of a clavicular

facet and the shift in position of the head to its dorsal surface; the presence of a sigmoid articular surface on the proximal end of the radius; the elongation and expansion of the olecranon process, the deep semilunar notch and carpel articulation of the ulna; the increased relative width of the bones of the manus; the presence of an accessory falciform bone and the development of strong, nail-like claws.

As regard the position of the bones in the articulated forelimb the most salient features are as follows: the craniad shift in position of the shoulder-girdle due to the elongation of the manubrium; the rotation of the scapula resulting in its original dorsal border facing caudad and its glenoid cavity directed craniad; the abduction of the humerus to a ninety-degree angle accompanied by extreme medial rotation resulting in its original lateral border facing craniad and its distal end projecting antero-laterad; the lack of a distal radio-ulnar articulation; the uncrossed position of the radius and ulna with the radius situated antero-mediad and the ulna postero-laterad so that their original volar surfaces face postero-mediad and the palm of the manus postero-laterad, with the pollex directed caudad and the fifth digit craniad.

The chief fossorial adaptations manifested by the muscles of the forelimb of the mole are such features as the following: the great development of certain muscles, as for example the teres major, latissimus dorsi, pectoralis major and palmaris longus, which serve to put the limb in its peculiar position as well as into action; the absence of certain muscles normally present in the mammalian forelimb, as for example, the mastoideohumeralis (brachiocephalicus), scapulohumeralis posticus (capsularis), coracobrachialis, brachioradialis, supinator, pronator quadratus, abductor pollicis longus, flexor carpi radialis and the intrinsic muscles of the manus; the acquisition of new points of origin of the biceps brachii and the long head of the triceps brachii and the change in action of certain muscles, as for example, the occipital portion of the rhomboideus anterior, the teres major and deltoid due to alteration of position of the forelimb.

It is evident that the normal position of the brachium of the mole, that is abduction accompanied by extreme medial rotation, is maintained by active muscular contraction. The muscles acting on the humerus to produce abduction and medial rotation are the latissimus dorsi, teres major and minor,

infraspinatus, supraspinatus and subscapularis, assisted by the pectoralis major in rotation.

During the excavation of the underground tunnels the forelimb of the mole alternately swings backward and forward with great strength and rapidity, much in the same fashion as the swimming movements of man. The backward movement is, of course, the more powerful since it supplies the impetus resulting in pushing the earth aside, whereas, the forward swing serves to place the limb in a favorable position for the backward thrust. During the forward swing the brachium, antibrachium, manus and digits are extended and in the backward thrust these parts are powerfully flexed. Concurrent with these fundamental movements of the free forelimb are complimentary movements of the shoulder-girdle, that is forward (protraction) and backward (retraction), thus serving to impart added impetus to the movements of the free limb and to maintain the articular surfaces of the shoulder-joint in apposition.

The muscles acting on the various parts of the forelimb in the production of these movements are summarized as follows: extension (swinging forward) of the brachium at the shoulder-joint is produced by the anterior (superficial and deep) portion of the pectoralis major and the deltoid; flexion (swinging backward) of the brachium by the latissimus dorsi, infraspinatus, supraspinatus, teres major and minor, subscapularis, long head of the triceps brachii and the posterior (superficial and deep) portion of the pectoralis major; flexion of the antibrachium at the elbow-joint by the biceps brachii, brachialis and the volar antibrachial muscles, which arise from the medial (internal) epicondyle of the humerus (namely, pronator teres and palmaris longus); extension of the antibrachium by the triceps brachii, anconeus externus and internus and the dorsal antibrachial muscles, which arise from the lateral epicondyle of the humerus (namely, extensor carpi radialis, extensor digitorum communis, extensor digiti quinti, and in part the extensor carpi ulnaris); flexion of the manus by the volar antibrachial muscles (palmaris longus, flexor carpi ulnaris, and flexor digitorum sublimis and profundus); extension of the manus by the dorsal antibrachial muscles (extensor carpi radialis and ulnaris, extensor digitorum communis, extensor digiti quinti, extensor pollicis et indicis and the extensor ossis metacarpi pollicis); while flexion and extension of the digits

are produced by the flexor and extensor digitorum muscles, respectively.

Protraction of the shoulder-girdle is brought about by the action of the trapezius and rhomboideus anterior and levator scapulae while retraction is produced by the subclavius, pectoralis minor, trapezius posterior, possibly the serratus anterior and indirectly the latissimus dorsi and posterior portion of the pectoralis major.

The nerves which supply the muscles of the forelimb exhibit no striking peculiarities other than the course which the musculocutaneous, median, ulnar and radial nerves take, namely, round the postero-lateral boundary of the axilla rather than the antero-medial as in typical mammals. The peculiar course of these nerves is indubitably due to the pronounced medial rotation of the brachium.

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BIBLIOGRAPHY

Dobson, G. E. 1882. A monograph of the Insectivora. London.
Flower, W. H. 1885. Osteology of the Mammalia. London.
Lull, R. S. 1926. Organic Evolution. N. Y.
Quain, Jones. 1923. Elements of Anatomy, vol. IV, part II.
Shimer, H. W. 1903. Fossorial Adaptations. American Naturalist, vol. 37.
Slonaker, J. R. 1920. Some morphological changes for adaptation in the Mole. Jour. Morph., vol. 34.
True, F. W. A revision of the American Moles. Proc. of the U. S. Nat. Museum, vol. 19.

ABBREVIATIONS

A—acromion
AB—ventral (axillary) border of scapula
AE—anconeus externus
AI—anconeus internus
AL—acromioclavicular ligament
ATN—anterior thoracic nerves
B—biceps brachii
B′—tendon of biceps
BR—brachialis
C—coracoid
C′—carpus
C″—capitulum
CA—capitate
CE—centrale
CF—clavicular facet
CF′—navicular facet
CP—coronoid process
D—deltoid
DB—dorsal (posterior) border
DT—deltoid tuberosity
ECR—extensor carpi radialis
ECU—extensor carpi ulnaris
EDC—extensor digitorum communis
EDQ—extensor digiti quinti proprius
EJ—elbow-joint
EMP—extensor ossis metacarpi pollicis
EP—extensor pollicis et indicis
F—foramen
F′—facet
F″—fossa
FA—falciform bone
FCU—flexor carpi ulnaris
FDP—flexor digitorum profundus
FDS—flexor digitorum sublimis
G—groove
GF—glenoid fossa
GM—greater multangular
GT—greater tuberosity
H—humurus
H^1—hook-like process
H^2—hamate
HA—humeroabdominalis
HD—humerodorsalis
HF—humeral facet
I—infraspinatus
IF—infraspinous fossa
IG—intertubercular groove (canal)
IT—infraglenoid tubercle
L—lunate
L′—latissimus dorsi
L″—tensor fasciae antibrachii
L_1—medial lamina on lesser tuberosity
L_2—lateral lamina (bicipital ridge)
L_3—point of insertion of latissimus dorsi and teres major
LE—Lateral epicondyle
LF—lunate facet
LM—lesser multangular
LS—levator scapulae
LTN—long thoracic nerve
M_{1-2}—metacarpal bones
MCN—musculocutaneous nerve
MN—median nerve
N—navicular
N_{1-2}—notch
NF—navicular facet
NS—median, ulnar and radial nerves
OF—olecranon fossa
OP—olecranon process
P—anterior superficial pectoralis
P′—posterior superficial pectoralis
P″—anterior deep pectoralis
P‴—posterior deep pectoralis
Pb—pisiform
P_{1-3}—phalanges
PL—palmaris longus
PM—pectoralis minor
PR—pectoralis ridge
PT—pronator teres
R—radius
RAC—rhomboideus anterior (cervical portion)
RAO—rhomboideus posterior (occipital portion)
RF—Radial fossa
RF′—radial facet
RN—radial nerve
RP—rhomboideus posterior
S—scapula
S′—supraspinatus
S″—subscapularis
SC—sigmoid cavity
SC′—subclavius
SF—sternal facet
SF′—supracondylar foramen
SF_1—supraspinous fossa
SF_2—subscapular fossa
SJ—shoulder-joint
SM—serratus magnus (anterior)
SN—semilunar notch
S^1N—nerve to subclavius muscle
SP—spine
SS—suprascapula
SSN—suprascapular nerve
S′SN—subscapular nerve
ST—sternum
ST′—subclavian tubercle
T—tuberosity
TA—trapezius anterior
TE—external head of triceps brachii
TI—internal head of triceps brachii
TM—teres major
TM′—teres minor
TN-T′N—nerves to humerodorsalis and humeroabdominalis
TP—trapezius posterior
TR—triquetral
TRO—trochlea
TS—long (scapular) head of triceps brachii
U—ulna
UF—ulnar facet
UN—ulnar nerve

THE COMPARATIVE ANATOMY OF THE THYROID AND ADRENAL GLANDS IN WILD ANIMALS

ROBERT CRILE

The hypothesis underlying the investigation described in the following pages is that the adrenals and the thyroid are the energy-controlling glands of the body; that the energy characteristics of the animal depend primarily on the thyroid-adrenal relationship. Being a gland of steady and continuous activity, one would expect that the thyroid gland would be large in the more highly sensitized and active animals, and that it would be relatively small in those animals that are slow or that carry special means of protection, such as poison, carapace or offensive odor.

In the human being the thyroid gland has more than twice the weight of the adrenal glands. Since man differs in his energy characteristics from animals in the wild state, the question arises whether such animals differ widely from man and from each other with respect to the development of these energy regulators.

The adrenal glands are emergency glands (Cannon), which are called into action for sudden needs rather than for long cycles, like the thyroid gland. Therefore, it may be assumed that the adrenal glands control the explosive outbursts of energy. The secretion of the adrenal gland, discharged into the blood stream, empowers the animal for a short time with a strength and speed far beyond that of its ordinary range.

From the above considerations we inferred that the relative sizes of the adrenal and thyroid glands of animals might vary according to the energy characteristics and habits of the animals. In fact, we believed that the energy characteristics of animals, so far as activity is concerned, might almost be determined by a comparative study of the relative sizes of the thyroid and the adrenal glands and by their relations to the body weights.

To test these points, during the past three years, I have obtained specimens of the thyroid and adrenal glands of a widely separated variety of animals, in order to determine the relationship between the size of the animal and the weights

of these important glands as well as the energy characteristics of the animals. The research, although not completed, would seem to support the theory that such relationships exist.

The Crile-Bole-Fuller Expedition was organized in October, 1931. Although the main objective was to secure specimens of the fauna of the Southwestern States, one objective was to secure evidence whereby to test the validity of this theory. The members of the expedition were: Arthur B. Fuller, George W. Phillips, and Benjamin P. Bole, Jr., of the Staff of The Cleveland Museum of Natural History; Harold L. Madison, Jr., and myself, my purpose being to secure weights of the brain, thyroid and adrenal glands of as many species of animals as possible. The research has included three collections:

First: The glands of wild animals collected in Arizona.

Second: The glands of domestic and of wild animals collected in the vicinity of Cleveland, and of wild animals collected from importers and zoological gardens in Cleveland, New York, Detroit, California, etc.

Third: The glands of domestic and of wild animals collected in Cumberland Island, Georgia, and the extreme South of Florida.

All these glands were preserved in Klotz Solution. They were weighed and photographed and submitted to Dr. Allen Graham, of the Cleveland Clinic Foundation, for microscopic examination. Only normal glands are used in the averages given in the following section, entitled, "Findings."

The first collection was secured October-December, 1931, at Agassiz Peak in the Coconino Forest Reserve, near Flagstaff, Arizona; in the San Francisco Crater, immediately overlooking Flagstaff; at Schultz Pass; at Seligman; at Oakland, Arizona; in the Kaibab Forest; in Oak Creek Canyon; in The White Tank Mountains (near Flagstaff, Arizona) and in the Catalina Mountains, at altitudes varying from 2,000 to 12,000 feet. One hundred and seventeen sets of glands were collected in the Southwestern Expedition, including those of small rodents varying in size from the small mountain meadow mouse to the large Mexican pack rat; of the gopher, the prairie dog and the rabbit; of many varieties of squirrels and chipmunks; of several varieties of skunks; of the lynx, coyote, mountain lion, peccary (wild pig); mule deer and white-tailed deer.

On my return to Cleveland, I continued this study of the comparative size of the thyroid and adrenal glands and col-

lected thirty-three sets of glands of such domestic animals and wild animals as could be found about Cleveland, as well as of animals from the zoological gardens of Detroit and Cleveland. However, inasmuch as the thyroid glands of the domestic animals from the slaughterhouses in Cleveland were goiterous, as were those of the wild animals from the Zoological Gardens of Cleveland and Detroit, such as a black bear (*Euarctos americanus*), a baboon (*Cynocephalus hamadryas*), a chita (*Acynonyx jubatus*), an axis or spotted deer (*Cervus axis*), and lions (*Felis leo*) and since Dr. Graham, of the Cleveland Clinic Foundation, found that the thyroid glands of the Arizona white-tailed deer, the peccary, and the coyote collected in Arizona were goiterous, it seemed as if it might be interesting to compare the observations of animals in goiter belts with those of animals that had been bred in a comparatively "goiter-free country," such as Florida which, having ocean on both sides, should not be lacking in iodine.

Through the courtesy of Dr. T. S. Field, Dr. F. W. Beck, and Farris and Company, of Jacksonville, Florida, I had the opportunity to collect eighteen sets of glands of cattle, including bulls, steers and cows, pregnant and non-pregnant animals which in appearance were sleek and rugged. The glands were collected immediately after death. In only four instances out of the series of eighteen, i. e., in 22 per cent of the cases, did the weight of the thyroid gland exceed that of the adrenal glands. In Cleveland, out of a series of twenty-eight, in twenty-two instances, 75 per cent, the weight of the thyroid gland exceeded that of the adrenal glands.

In the winter of 1933, through the courtesy of Dr. P. C. Perry and by permission of Mr. Morrison Carnegie, Mr. Fuller of the Cleveland Museum of Natural History, who was a member of the Southwestern Expedition, and I had the added opportunity of collecting various types of wild animals from Cumberland Island, one of the most southern of the Golden Islands of Guale. Cumberland Island afforded an untouched wild life from which were collected specimens of the Florida white-tailed deer, wild pig, raccoon, pocket gopher and alligator. From Southern Florida we secured a crocodile as well as an alligator, representing the sluggish, inactive type of animal, a direct contrast to the alert, habitually active deer.

FINDINGS

Mice

(*Microtus alticola alticola; Peromyscus; Sorex vagrans monticola; Onychomys*—Mountain Meadow Mouse; Deer Mouse; Shrew; Grasshopper Mouse)

Characteristics: These four types of mice differ considerably in characteristics. Where we found them, the Shrew (*Sorex vagrans monticola*) is the smallest, the Deer Mouse (*Peromyscus*) is next in size, and the Mountain Meadow Mouse (*Microtus alticola alticola*) and the Grasshopper Mouse (*Onychomys*) are the largest. I understand, however, that in different parts of the country the relative sizes of these four types vary.

The *Sorex vagrans monticola* and the *Onychomys* are faster and more active than the *Microtus* or the *Peromyscus*. The *Peromyscus* travels on top of the ground; the *Microtus* moves in tunnels. The *Onychomys* lives largely in trees, and, like the *Sorex*, chases and eats the others.

The Thyroid Gland: In all of these varieties of mice the thyroid lobes appeared as long, reddish bodies, lying one on either side of the larynx and a little below it. There was probably an isthmus but it was broken by the slightest pressure. The lobes lay close to the trachea and usually were bound down by a little overlying tissue.

The Adrenal Glands: The adrenal glands in these four types of mice lay at the upper tip of the kidneys. In the *Microtus*, the *Peromyscus* and the *Onychomys* they were so closely attached to the kidneys by a thin membrane of tissue that they seemed to be a part of the kidneys. In the *Sorex* they were separated from the kidneys, lying nearer the blood supply. In shape the adrenal glands were oval or more nearly round; in color, greyish.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Onychomys* (Grasshopper Mouse) the average weight of the thyroid gland was 1.23 mg.; of the adrenal glands, 29.16 mg.; the adrenal glands thus being 23.7 times as large as the thyroid gland (Plate I, Figure 1). In the *Sorex vagrans monticola* (Shrew), the weight of the thyroid gland was 1.6 mg.; of the adrenal glands, 6.2 mg., the adrenal glands being 3.9 times as large as the thyroid gland (Plate I, Figure 2). In the *Microtus alticola alticola* (Mountain Meadow Mouse) the average weight of the thyroid gland was 2.2 mg.; of the adrenal glands, 8.12 mg., the adrenal glands being 3.7 times as large as the thyroid glands (Plate I, Figure 3). In the *Peromyscus* (Deer Mouse), the average weight of the thyroid gland was 2.25 mg.; of the adrenal glands, 6.4 mg., the adrenal glands being 2.8 times as large as the thyroid gland (Plate I, Figure 4).

Squirrels

(*Sciurus fremonti mogollonensis, Sciurus arizonensis, Sciurus aberti*—Pine or Red Squirrel, Grey Squirrel, Abert's Squirrel)

Characteristics: The Pine or Red Squirrel (*Sciurus fremonti mogollonensis*) is extremely alert, not timid, and very active, leaping about in the trees at high speed all day and far into the night. It does not hibernate.

The Arizona Grey Squirrel (*Sciurus arizonensis*) is larger than the Pine or Red Squirrel. In activity it ranges between the Pine or Red Squirrel and the Abert's Squirrel and is more wary than the Pine Squirrel. It partially hibernates in the winter.

The Abert's Squirrel (*Sciurus aberti*) is larger and less active than either the Pine or Red Squirrel or the Arizona Grey Squirrel. In comparison, the Abert's Squirrel is a fat and lazy animal, not alert and not timid.

The Thyroid Gland: In the Pine or Red Squirrel, the lobes of the thyroid gland were long and red and were connected by an isthmus. The position of the lobes was the same as that of the thyroid glands in mice, but the gland was larger in relation to the size of the animal.

In the Arizona Grey Squirrel the lobes of the thyroid gland were long and were connected by an isthmus.

In the Abert's Squirrel the thyroid gland was a little larger than in the Pine or Red Squirrel.

The Adrenal Glands: In the Pine or Red Squirrel the adrenal glands were grey. They lay almost under the kidneys and out of sight. They were long and sausage-like in shape, and were so closely attached to the kidney that they were often flat on one side.

In the Grey Squirrel the adrenal glands were yellowish and long. They lay at the inner side of the kidneys.

In the Abert's Squirrel the adrenal glands were roundish but small. They lay at the upper-inner tip of the kidneys and extended downward.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands of the *Sciurus fremonti mogollonensis* (Pine or Red Squirrel) was 9.5 mg.; of the adrenal glands, 86.9 mg., the adrenal glands being 9.15 times as large as the thyroid gland (Plate I, Figure 5).

In the *Sciurus arizonensis* (Grey Squirrel) the weight of the thyroid gland was 26 mg.; of the adrenal glands, 197 mg., the adrenal glands being 7.58 times as large as the thyroid gland (Plate I, Figure 6).

In the *Sciurus aberti* (Abert's Squirrel) the average weight of the thyroid glands was 30.1 mg.; of the adrenal glands, 204 mg., the adrenal glands being 6.77 times as large as the thyroid gland (Plate I, Figure 7).

CHIPMUNKS AND GROUND SQUIRRELS

(*Eutamias, Ammospermophilus, Citellus, Callospermophilus*—
Chipmunk, Antelope Chipmunk, Ground Squirrel,
Mantle Ground Squirrel)

Characteristics: The Chipmunk (*Eutamias*) is very alert. It is not quite so active as the Pine or Red Squirrel, but is more active than the Abert's Squirrel. It is vegetarian and migratory.

The Antelope Chipmunk (*Ammospermophilus*) is about the size of the Chipmunk and is fully as active, if not more so.

The Ground Squirrel (*Citellus*) is about the size of the Chipmunk and the Antelope Chipmunk, but is not so active as either.

The Mantle Ground Squirrel (*Callospermophilus*) is less active than the Pine or Red Squirrel, more active than the Abert's Squirrel, and less active than the Chipmunk. In size, it is about twice as large as the Chipmunk.

The Thyroid Gland: In the Chipmunk the thyroid gland consisted of two lobes lying one on either side of the larynx, and it had an isthmus.

In the Antelope Chipmunk the lobes of the thyroid gland were long and red but small, and lay below the larynx.

In the Ground Squirrel the lobes of the thyroid gland were long and red, but small.

In the Mantle Ground Squirrel the lobes of the thyroid gland were light red, long and large, and were connected by an isthmus.

The Adrenal Glands: In the Chipmunk the adrenal glands were long and grey and lay under the kidneys like those of the Pine or Red Squirrel. In comparison with the adrenal glands of the Pine or Red Squirrel, they were smaller but were larger than those of the Abert's Squirrel.

In the Antelope Chipmunk the adrenal glands were large and grey and long. They lay at the upper-inner tip of the kidney, extending almost to the center of the kidney.

In the Ground Squirrel the adrenal glands were brown in color, long and small. They lay at the upper-inner tip of the kidney and extended down toward the center, lying very close to the kidney.

In the Mantle Ground Squirrel the adrenal glands were yellowish in color, long and large. They lay at the upper-inner side of the kidney.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands of the *Eutamias* (Chipmunk) was 2.03 mg.; of the adrenal glands, 15.08 mg., the adrenal gland being 7.4 times as large as the thyroid gland (Plate I, Figure 8).

The average weight of the thyroid glands of the *Ammospermophilus* (Antelope Chipmunk) was 6.4 mg.; of the adrenal glands, 39 mg., the adrenal glands being 6.09 times as large as the thyroid gland (Plate I, Figure 9).

The weight of the thyroid gland of the *Citellus* (Ground Squirrel) was 4 mg.; of the adrenal glands, 19 mg., the adrenal glands being 4.75 times as large as the thyroid gland (Plate I, Figure 10).

The weight of the thyroid gland of the *Callospermophilus* (Mantle Ground Squirrel) was 9.5 mg.; of the adrenal glands, 35 mg., the adrenal glands being 3.68 times as large as the thyroid glands (Figure 11).

PRAIRIE DOG
(*Cynomys*)

Characteristics: Although the Prairie Dog (*Cynomys*) is supposed to be an active animal and covers quite a bit of ground in the vicinity of its hole, it is a timid animal and depends upon its ability to get into its hole quickly in order to escape its enemies. So, although its activity is limited in range, it is alert and runs rather fast for its size. The Prairie Dog begins its hibernating season in November, and at the time of our expedition many of them were in hibernation.

The Thyroid Gland: The thyroid gland of the Prairie Dog was large, red and long, usually lying below the larynx.

The Adrenal Glands: The adrenal glands were brown, oval and small, lying on a level with the upper-inner tip of the kidney, but quite separated from the kidney.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid gland of the *Cynomys* (Prairie Dog) was 25 mg.; of the adrenal glands, 28 mg., the adrenal glands being 1.12 times as large as the adrenal glands (Figure 12).

POCKET GOPHER

(*Thomomys*)

Characteristics: The Pocket Gopher (*Thomomys*) relies entirely upon its digging powers for food and escape. It is not a very active animal, that is, it does not cover much ground, but is alert and possesses a well-developed pair of front legs with which it digs for roots and digs tunnels in which to store them.

The Thyroid Gland: In each of the series of 39 gophers examined, the thyroid gland consisted of two lobes, dark reddish in color and almost oval in shape. The lobes were not very long and were flat on the inner side. They lay on either side of the larynx, but below and entirely separated from it.

The Adrenal Glands: The adrenal glands were dark grey in color, and almost oval in shape. They were larger in some animals than in others and were sometimes flat on one side and occasionally on both sides. They usually lay at the upper-inner side of the kidney, but separated from it by tissue.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid gland of the *Thomomys* (Pocket Gopher) was 3.95 mg.; of the adrenal glands, 11.88 mg., the adrenal glands being three times as large as the thyroid gland (Plate I, Figure 13).

RATS

(*Neotoma, Dipodomys, Mus Norvegicus*—Mexican Pack Rat, Kangaroo-Rat, and Gray Norway Rat)

Characteristics: The Mexican Pack Rat (*Neotoma*) is a bold, lumbering animal with large teeth. It does not show any excessive degree of speed, but works all night carrying away objects which are often in excess of its own weight.

The Kangaroo-Rat (*Dipodomys*) is about the size of the Chipmunk, and its cheek pouches resemble those of the Pocket Gopher. The Kangaroo-Rat burrows beneath rocks. It is more active than the Mexican Pack Rat and has elongated hind legs, large eyes, well developed ears, and a long tail.

The Thyroid Gland: In each of our series of sixteen Mexican Pack Rats the lobes of the thyroid gland were long, reddish-brown in color and were connected by an isthmus. One lobe lay on either side of the larynx, half its length extending over the trachea. In every specimen there was a very definite isthmus.

In the Kangaroo-Rat the lobes of the thyroid gland were dark red and flat. They were wide at the top, narrower toward the base and lay right over and extended below the larynx and were connected by an isthmus.

The Adrenal Glands: In the Mexican Pack Rat the adrenal glands were light grey in color. They were long and often were attached to the kidneys, being flat on the attached side and rounded on the other. In most cases they were attached at the middle of the upper end of the kidneys and were held down by a thin membrane, but in some instances they lay near the inner side of the upper end of the kidneys and were separated from them by tissue.

In the Kangaroo-Rat the adrenals were grey and oval. They lay at the inner-lower end of the kidneys, separated by tissue.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Neotoma* (Mexican Pack Rat) the average weight of the thyroid gland was 11.1 mg.; of the adrenal glands, 61.7 mg., the adrenal glands being 5.56 times as large as the thyroid gland (Plate I, Figure 14).

In the *Dipodomys* (Kangaroo-Rat) the average weight of the thyroid gland was 1.15 mg.; of the adrenal glands, 6 mg., the adrenal glands being 5.22 times as large as the thyroid gland (Plate I, Figure 15).

In the ordinary *Mus Norvegicus* (Grey Norway Rat) which is large, alert, and fierce, the thyroid gland was 8 mg.; the adrenal glands, 62 mg., the adrenal glands being 7.75 times as large as the thyroid gland (Plate II, Figure 16).

MUSK-RAT OR MUSQUASH
(Ondatra zibethica)

Characteristics: The Musk-Rat is largely a water animal. It is slow and massively built, the average weight being about two pounds. In character it is sly but, like the brown rat, it may be very savage. Its food consists of grasses, fish, and even carrion.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Ondatra zibethica* (Musk Rat) the weight of the thyroid gland was 43 mg.; of the adrenal glands, 156 mg., the adrenal glands being 3.63 times as large as the thyroid glands (Plate II, Figure 17).

WOODCHUCK
(Marmota monax monax)

Characteristics: The Woodchuck does not store food for the winter. It hibernates completely. Its average weight is from eight to ten pounds. Although we had several Woodchucks in our series, those in hibernation and just out of hibernation were of special interest.

Relative Sizes of the Thyroid and Adrenal Glands: One of our specimens of *Marmota monax monax* (Woodchuck) was dug out in early winter while still asleep, and was killed instantly. The weight of the thyroid gland was 197.5 mg.; of the adrenal glands, 172.5 mg., *the thyroid gland being 1.14 times as large as the adrenals.*

A second Woodchuck was caught in February, just as it was coming out from hibernation. It moved slowly, was easily caught, caged and brought to the Cleveland Clinic where it showed little activity or desire to eat. After three days it was killed. The weight of the thyroid gland was 240 mg.; of the adrenal glands, 404 mg., *the adrenal glands being 1.68 times as large as the thyroid gland.*

Thus in two animals of practically the same weight the thyroid and adrenal glands weighed respectively 42.5 mg. and 231.5 mg. more in the animal just out of hibernation than in the animal in hibernation, while in the animal in hibernation the thyroid gland was larger than the adrenal glands and in the animal out of hibernation this relation was reversed, the adrenal glands being larger than the thyroid gland.

RABBITS

(*Silvilagus auduboni; Lepus californicus*—Cotton Tail Rabbit; Jack Rabbit)

In the Cotton Tail Rabbit (*Silvilagus auduboni*), caught near Cleveland, the average weight of the thyroid gland was 3.7 mg.; of the adrenal glands, 86.3 mg., the adrenal glands being 23.3 times as large as the thyroid gland (Plate II, Figure 18).

In our one Jack Rabbit (*Lepus californicus*) of Arizona, the thyroid gland weighed 147 mg., the adrenal glands 256 mg., the adrenals being 1.74 times as large as the thyroid gland (Plate II, Figure 19).

The average weight of the Cotton Tail Rabbit is 2.5 pounds; of the Jack Rabbit, 6 pounds.

RACCOON

(*Procyon lotor*)

Characteristics: The Raccoon (*Procyon lotor*) is carnivorous. It hibernates during the severe part of the winter. It is about 36 inches long, including its eight to ten-inch tail, and weighs from fifteen to twenty-five pounds.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Procyon lotor* (Raccoon), collected in Cumberland Island, Southern Georgia, in December, the weight of the thyroid gland was 222 mg., of the adrenal glands, 1,651 mg., the adrenal glands being 7.4 times as large as the thyroid gland.

FOXES

(*Urocyon cinereoargenteus scotti; Vulpes fulva*—Grey Fox; Red Fox)

Characteristics: Our series of Grey Foxes was collected in Arizona. The Grey Fox (*Urocyon cinereoargenteus scotti*) is an active, carnivorous animal, but does not depend on sudden outbursts of energy as does the deer. Its average weight is seven pounds.

The Thyroid Gland: The thyroid gland was long and lay below the larynx.

The Adrenal Glands: The adrenal glands were greyish-yellow in color, flat on one side and round on the other. They lay on the inner side of the kidneys but were separated from them. In two out of our six specimens the adrenal glands were not found in the same position in relation to the kidneys, and were constricted in the center, like a peanut.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands of the *Urocyon cinereoargenteus scotti* (Grey Fox) was 112.8 mg.; of the adrenal glands, 279.1 mg., the adrenal glands being 2.48 times as large as the thyroid gland (Plate II, Figure 20).

Our one specimen of the Red Fox (*Vulpes fulva*) was secured near Cleveland.

The Thyroid Gland: The thyroid gland seemed to be relatively large.

The Adrenal Glands: The adrenal glands were dissimilar in size, in form, and in their position in relation to the kidneys.

Relative Sizes of the Thyroid and Adrenal Glands: The weight of the thyroid gland of the *Vulpes fulva* (Red Fox) was 405 mg.; of the adrenal glands, 420 mg., the adrenal glands being 1.04 per cent larger than the thyroid glands.

CATS

(*Bassariscus; Felis domesticus*—Ring-Tailed Cat, Domestic Cat)

An interesting comparison was that between the adrenal-thyroid ratio in a Domestic Cat (*Felis domesticus*) and in the Ring-Tailed Cat (*Bassariscus*) secured in Arizona. In the latter the average weight of the thyroid gland was 88 mg.; the adrenal glands 353.5 mg., the adrenals being four times as large as the thyroid gland (Plate II, Figure 21). In the domestic cat the thyroid gland weighed 216 mg.; the adrenal glands 518 mg., the adrenal glands being only 2.4 times as large as the thyroid gland (Figure 22).

SKUNKS

(*Spilogale; Conepatus mesoleucus; Mephitis;* Civet Cat or Spotted Skunk; Hog-Nosed Skunk; Common or Hooded Skunk)

Characteristics: Skunks are slow and deliberate; even when frightened they do not move rapidly. They are carnivorous and hibernate only in severe winters.

The Civet Cat or Spotted Skunk (*Spilogale*) is smaller than the Hooded or Common Skunk and is largely arboreal.

The Hooded Skunk (*Mephitis*) is about the size of a cat, but is heavier and more stockily built.

The Hog-Nosed Skunk (*Conepatus mesoleucus*) is the largest of the three and the least active.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid gland of the *Spilogale* (Civet Cat) was 17.8 mg.; of the adrenal glands, 79.2 mg., the adrenals being 4.4 times as large as the thyroid gland.

The weight of the thyroid gland of the *Mephitis* (Common Skunk) was 96 mg.; of the adrenal glands, 348 mg., the adrenal glands being 3.62 times as large as the thyroid gland (Figure 23).

The average weight of the thyroid gland of the *Conepatus mesoleucus* (Hog-nosed Skunk) was 93 mg.; of the adrenal glands, 277.5 mg., the adrenal glands being 2.98 times as large as the thyroid gland (Figure 24).

PORCUPINE

(*Erethizon dorsatum*)

Characteristics: The Canadian Porcupine (*Erethizon dorsatum*) weighs from fifteen to twenty pounds. It is slow, clumsy and unafraid.

It is largely nocturnal and does not hibernate. Its food consists of leaves, bark, pods, etc.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Erethizon dorsatum* (Porcupine) procured from Canada, the weight of the thyroid gland was 360 mg.; of the adrenal glands, 375 mg., the adrenal glands being 1.04 times as large as the thyroid gland.

COLLARED PECCARY

(*Pecari angulatus*)

Characteristics: The peccary (*Pecari angulatus*) is very agile and alert. It climbs mountains like a mountain goat and has great endurance. It moves rapidly for short distances and covers long distances at a time, sometimes twenty miles without a stop. It may be quite savage.

The Thyroid Gland: The lobes of the thyroid glands in our two specimens were very long, varying from three inches in length in one, to four and a half inches in length in the other. In both specimens the lobes were flat and hard and were connected by a wide isthmus.

The Adrenal Glands: The adrenal glands were bluish-grey, large, and approximately oval in shape except that one end was larger than the other and they were well separated from the kidneys.

Relative Sizes of the Thyroid and Adrenal Glands: The thyroid-adrenal ratios of these specimens are invalid as Dr. Allen Graham found both thyroid glands hyperplastic, in fact, in one the hyperplasia was "sufficient to be considered an exophthalmic goiter."

The weights, however, are interesting, if for no other reason than the size of the goiter.

Total Thyroid including isthmus	Total Adrenal
1200 mg	1800 mg.
20000 mg	2600 mg.

DEER

(*Homionus odocoileus, Odocoileus couesi, Odocoileus virginianus*—
Mule Deer, Arizona White-Tailed Deer, Florida
White-Tailed Deer)

MULE DEER

Characteristics: The period when we were in Arizona was the mating season for the very active migratory Mule Deer (*Homionus odocoileus*) which depends upon speed for its escape from its enemies. It moves in leaps and bounds, all feet leaving the ground simultaneously. For short distances the Mule Deer maintains a very rapid pace. Its weight ranges from 150 to 250 pounds.

The Thyroid Gland: The lobes of the thyroid gland of the Mule Deer were light or dark red in color, long, and with rounded ends. They lay far beneath the larynx with the lower ends out of sight, and had a large blood supply running throughout the gland. In none of our specimens did I find an isthmus.

The Adrenal Glands: The adrenal glands were dark grey, almost brownish in color, and oval in shape. They lay at the upper-inner side of the kidneys which were close to the vena cava.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands was 2,725 mg.; of the adrenal glands, 5,425 mg., the adrenal glands being 1.99 times as large as the thyroid gland (Figure 27).

ARIZONA WHITE-TAILED DEER

Characteristics: The Arizona White-Tailed Deer (*Odocoileus couesi*) is only half the size of the Mule Deer. Like the Mule Deer, it covers the ground in leaps and bounds and in comparison with the Mule Deer would seem to be more active. It climbs mountains with the ease and agility and endurance of a mountain goat. The weight of the Arizona While-Tailed Deer ranges from 100 to 150 pounds.

The Thyroid Gland: The lobes of the thyroid glands of the Arizona White-Tailed Deer were red, large and long and had a large blood supply.

The Adrenal Glands: The adrenal glands of the Arizona White-Tailed Deer were dark, bluish-grey in color. They were large, were flat on both sides and had rounded edges. In some specimens they lay in different positions in relation to the kidneys, but usually they lay at the upper-inner side of the kidneys and were separated from them.

Relative Sizes of the Thyroid and Adrenal Glands: The relative sizes of the thyroid and adrenal glands of the Arizona White-Tailed Deer (*Odocoileus couesi*) are invalid, as Dr. Allen Graham found that all the thyroid glands showed hyperplasia. The weights are interesting, however, the average weight of the thyroid was 2,125 gm.; of the adrenals, 2,550 gm., the adrenal glands being 1.2 times as large as the thyroid gland (Plate III, Figure 26).

FLORIDA WHITE-TAILED DEER

Characteristics: The climate in Cumberland Island where these deer were collected is tropical. The animals live in a jungle of palmetto, underbrush and marsh. They were in poor physical condition, owing to drought, and were infested with parasites.

The Thyroid Gland: The thyroid glands of all of our specimens were pathologically enlarged.

The Adrenal Glands: The adrenal glands in all specimens were solid, roundish bodies.

Relative Sizes of the Thyroid and Adrenal Glands: Although the pathologic enlargement of the thyroid gland of the Florida White-Tailed Deer (*Odocoileus virginianus*) invalidates the thyroid-adrenal ratio, it is worth mentioning that even with pathologic enlargement of the thyroid gland, the average weight of the thyroid glands was 2.46 gm., of the adrenal glands, 2.67 gm., the adrenal glands being 1.08 times as large as the thyroid glands (Plate III, Figure 27).

SEAL

(*Phoco richardii geronimensis*)

This seal had been in captivity for some years in the Brookside Zoo, Cleveland. Its death was due to violence.

Relative Sizes of the Thyroid and Adrenal Glands: The weight of the thyroid gland was 5,204 mg.; of the adrenal glands, 6,003 mg., the adrenal glands being 1.15 times as large as the thyroid gland in spite of the fact that pathological examination by Dr. Allen Graham revealed hyperplastic goiter (Plate III, Figure 28).

BIRDS

(*Buteo borealis*, *Bubo virginianus virginianus*—
Chicken Hawk, Horned Owl)

In a group of birds we found the following relationships between the thyroid and adrenal glands.

Relative Sizes of the Thyroid and Adrenal Glands: In the Chicken Hawk (*Buteo borealis*) the weight of the thyroid gland was 106.5 mg.; of the adrenal glands, 113.5 mg., the adrenal glands being 1.06 times as large as the thyroid gland.

In the Horned Owl (*Bubo virginianus virginianus*) the weight of the thyroid gland was 85 mg.; of the adrenal glands, 165 mg., the adrenal glands being 1.94 times as large as the thyroid gland.

BAT

(*Myotis lucifugus* or *Epitiscus fuscus*)

Relative Sizes of the Thyroid and Adrenal Glands: In the Bat (*Myotis lucifugus*) the weight of the thyroid gland was 3.3 mg.; of the adrenal gland, 5 mg., the adrenal glands being 1.51 times as large as the thyroid gland.

RHESUS MONKEY OF INDIA

(*Macacus rhesus*)

Relative Sizes of the Thyroid and Adrenal Glands: In three specimens of Rhesus Monkey (*Macacus rhesus*) the thyroid glands were normal in position and color, and there was no isthmus. The average weight of the thyroid glands was 194 mg.; of the adrenal glands, 467 mg., the adrenal glands being 2.45 times as heavy as the thyroid gland.

ALLIGATOR

(*Alligator mississipiensis*)

We have had three alligators at the Cleveland Clinic, one which was killed in the wild at Cumberland Island, Southern Georgia, and two which had been in captivity for several years in Florida. All were between nine and ten feet long and weighed from 250 to 300 pounds.

The alligator, though apparently a slow, sluggish animal, is capable of quick action when securing its prey, and at times is very aggressive and savage. In captivity, alligators often fight each other.

The Thyroid Gland: The thyroid gland of the alligator consisted of two small reddish cylindrical lobes with an isthmus and lay just below the bifurcation of the trachea.

The Adrenal Glands: The adrenal glands of the alligator were long and slender and grey. They lay close to, in fact, were almost imbedded in the testes or ovaries and were difficult to locate and to dissect.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands was 5,200 mg.; of the adrenal glands, 4,900 mg., the thyroid and adrenal glands thus being about the same weight (Plate III, Figure 30).

CROCODILE

(*Crocodilus americanus*)

Characteristics: The crocodile is more savage and more swift in action than the alligator.

The Thyroid Gland: The thyroid gland in the crocodile was bi-lobed and lay at the bifurcation of the trachea, one lobe on either side.

The Adrenal Glands: The adrenal glands were long, slender bodies and lay near the testes or ovaries. In shape, they were very much like the adrenals of the alligator.

We have had two crocodiles at the Cleveland Clinic, both of which had been in captivity at Musa Island, Florida, from two to three years.

Relative Sizes of the Thyroid and Adrenal Glands: In the case of one of these specimens the dissection was made out-of-doors under difficult conditions, and I was unable to secure all the adrenal tissue. The weight of the thyroid gland was 3,770 mg.

Another crocodile was shipped from Musa Island to the Cleveland Clinic where it was dissected under favorable conditions. The weight of the thyroid gland of this crocodile was 5,200 mg.; of the adrenal gland, 4,300 mg., the thyroid gland being 1.2 times as heavy as the adrenal glands. Pathologic examination of the thyroid gland revealed no hypertrophy or hyperplasia.

MOUNTAIN LION OR PUMA

(*Felis concolor*)

The Mountain Lion was secured in Arizona.

Characteristics: The Mountain Lion (*Felis concolor*) is an alert, lithe, active animal. It covers a large range of territory, is stealthy in its hunting, finally rushing upon its prey in a series of leaps, or springing down upon it from an elevation. It averages from three to four feet in length from the head to the root of the tail.

The lobes of the thyroid gland of the Mountain Lion were long and were connected by an isthmus.

The adrenal glands were triangular in shape. They were flat on both sides, but wide at the top. The left adrenal gland lay below the central line of the kidney, while the right adrenal gland lay above the central line of the kidney.

Relative Sizes of the Thyroid and Adrenal Glands: The thyroid gland in our specimen weighed 1,600 mg.; the adrenal glands, 4,100 mg., the adrenal glands being 2.56 times as large as the thyroid gland (Plate III, Figure 29).

AFRICAN LION

(*Felis leo*)

This research into the comparative anatomy of the thyroid and adrenal glands began in 1927 when Dr. George Crile, on a hunting expedition in Africa, made rough dissections of lions and antelopes in the field, finding in every instance that the adrenal glands were noticeably larger than the thyroid gland, exactly opposite to the relative sizes of these glands in man in whom the weight of the thyroid gland is approximately twice that of the adrenal glands. It was this observation that led to my participation in the Southwestern expedition of the Cleveland Museum of Natural History.

In all, we have dissected five lions at the Cleveland Clinic. The first was a full grown female of jungle-born parents, which was bred in captivity. It was purchased from the Detroit Zoological Gardens, which are within the goiter belt. Dr. Allen Graham examined the thyroid gland and found a colloid goiter with hyperplasia.

The second lion was a female, six months old, bred in California. In this lion also Dr. Graham found a large colloid goiter with hyperplasia.

The third lion was a young female killed in combat. The glands were given to the Cleveland Clinic Research Department through the courtesy of Mr. Clyde Beatty. Dr. Allen Graham found a colloid goiter with hyperplasia.

The fourth lion was a mature male, weighing 356 pounds. It was secured from a zoological garden in Pennsylvania where it had been born seventeen years before. It was in good condition. Dr. Graham found a large colloid goiter with hyperplasia.

The fifth lion was a young female, only a year and a half old. It had a goiter.

The data regarding these goiterous animals collected from zoological gardens are introduced merely for general interest, but have no bearing upon our research.

	Thyroid	Adrenals
Lion No. 1	23,500 mg.	14,500 mg.
Lion No. 2	7,418 mg.	7,247 mg.
Lion No. 3	9,170 mg.	5,750 mg.
Lion No. 4	1,412 mg.	24.9 mg.
Lion No. 5	165 mg.	150 mg.

SUMMARY

1. In the wild state, the adrenal glands are larger than the thyroid gland, with a ratio as high as twenty-three to one in certain small rodents. In a human, the thyroid gland is larger than the adrenal glands, the ratio being two to one.

2. According to our data, a larger size of the thyroid gland in relation to the adrenal glands would seem to be a characteristic of the human being only.

3. Domestic animals from the territory in which goiters appear in man had goiters. Wild animals in captivity in these regions also had goiters. Therefore, a comparison of the weights of the thyroid and adrenal glands of these goiterous animals were not of value.

4. In Florida, domestic and wild animals were free from goiter.

APPRECIATION

I wish to express my appreciation to my father, Dr. George Crile, for making these expeditions possible and for permitting me to participate in them. To him I am indebted for the theory to test the validity of which this research was undertaken.

To Dr. E. S. A. King, formerly of the Cleveland Clinic Foundation, and to Dr. E. L. Walsh, I am indebted for their aid in preparing and photographing these specimens. To Dr. Allen Graham, of the Cleveland Clinic Foundation, I am indebted for the pathological examination of the specimens. To Daniel P. Quiring, Ph. D., of Western Reserve University, I am indebted for advice and supervision, and finally, I cannot adequately express my appreciation of the co-operation of every member of the Crile-Bole-Fuller Expedition.

PLATES I TO IV. PHOTOGRAPHS AND RELATIVE WEIGHTS OF THE THYROID AND ADRENAL GLANDS IN A SERIES OF THIRTY ANIMALS

(The numbers correspond to the numbers on the plates.)

No.	NAME OF ANIMAL	WEIGHT IN GRAMS			THYROID-ADRENAL RATIO
		Thyroid	Adrenals	Kidneys	
1	*Onychomys* (Grasshopper Mouse)	.0014	.04	.392	1 to 28.57
2	*Sorex vagrans monticola* (Shrew)	.0012	.0062	.221	1 to 5.17
3	*Microtus alticola alticola* (Mountain Meadow Mouse)	.0032	.0054	.172	1 to 1.69
4	*Peromyscus* (Deer Mouse)	.0015	.0068	.24	1 to 4.53
5	*Sciurus fremonti mogollonensis* (Pine or Red Squirrel)	.008	.091	1.626	1 to 11.37
6	*Sciurus arizonensis* (Grey Squirrel)	.026	.197	3.335	1 to 7.58
7	*Sciurus aberti* (Abert's Squirrel)	.051	.222	3.536	1 to 4.35
8	*Eutamias* (Chipmunk)	.0012	.020	.608	1 to 16.7
9	*Ammospermophilus* (Antelope Chipmunk)	.0028	.038	.807	1 to 13.57
10	*Citellus* (Ground Squirrel)	.004	.019	1.09	1 to 4.75
11	*Callospermophilus* (Mantle Ground Squirrel)	.0095	.035	1.415	1 to 3.68
12	*Cynomys* (Prairie Dog)	.025	.028	2.564	1 to 1.12
13	*Thomomys* (Pocket Gopher)	.0012	.0085	1.172	1 to 7.08
14	*Neotoma* (Mexican Pack Rat)	.019	.137	2.353	1 to 7.21
15	*Dipodomys* (Kangaroo Rat)	.01	.04	.947	1 to 4
16	*Mus norvegicus* (Gray Norway Rat)	.008	.062	.....	1 to 7.75
17	*Ondatra zibethica* (Musk-Rat of Musquash)	.043	.156	5.16	1 to 3.63
18	*Sylvilagus auduboni* (Cotton-Tail Rabbit)	.030	.090	4.630	1 to 3
19	*Lepus californicus* (Jack Rabbit)	.147	.256	19.34	1 to 1.74
20	*Urocyon cinereoargenteus scotti* (Grey Fox)	.160	.371	29.4	1 to 2.32
21	*Bassariscus* (Ring-Tailed Cat)	.080	.387	10.25	1 to 4.84
22	*Felis domesticus* (Domestic Cat)	.216	.518	23.9	1 to 2.4
23	*Mephitis* (Common or Hooded Skunk)	.096	.348	6.91	1 to 3.62
24	*Conepatus mesoleucus* (Hog-Nosed Skunk)	.054	.211	7.51	1 to 3.9
25	*Hemionus odocoileus* (Mule Deer)	2.00	5.750	.....	1 to 2.87
26	*Odocoileus couesi* (Arizona White-Tail Deer)	1.650	2.400	85.00	1 to 1.45*
27	*Odocoileus virginianus* (Florida White-Tail Deer)	2.460	2.670	.....	1 to 1.08
28	*Phoco richardii geronimensis* (Seal)	5.204	6.003	.....	1 to 1.15
29	*Felis concolor* (Mountain Lion)	1.6	4.1	140.00	1 to 2.56
30	*Alligator mississipiensis*	3.5	4.0	.....	1 to 1.14

*Histologic examination showed a marked hyperplasia of the thyroid gland.

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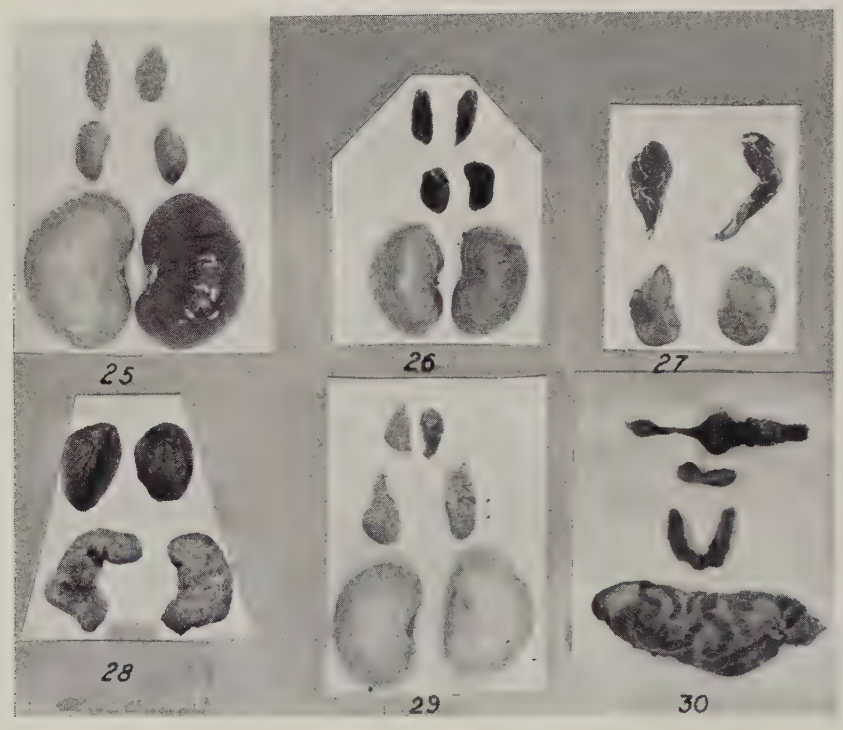
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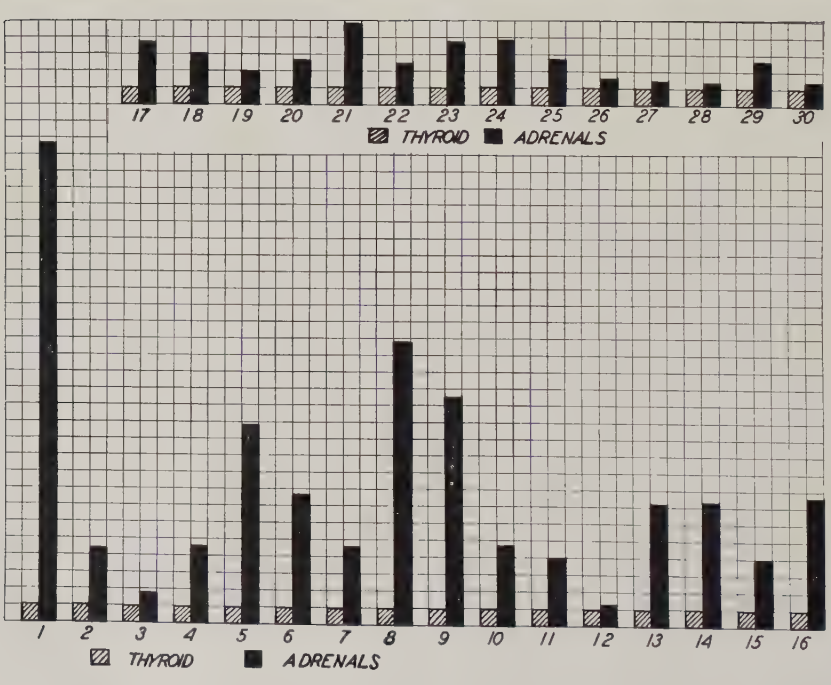
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THYROID ADRENALS
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THYROID ADRENALS

NOTE ON THE PRODUCTION OF FRUITING BODIES OF COPRINUS MICACEUS IN CULTURE[1]

S. S. HUMPHREY

During 1927 and 1928, the writer made some studies of the sex reactions of the common glistening ink cap fungus, *Coprinus micaceus* (Bull.) Fr. In this work fruiting bodies were produced in pure cultures started from spores. The methods employed differ in some respects from those used by other investigators of the sex reactions of the higher Basidiomycetes and, with the results, may prove of interest to many in the botanical field.

Fruiting bodies of *Coprinus micaceus* were found growing abundantly in several locations within a few city blocks of the Ohio State University campus and thus a constant source of supply was assured throughout most of the summer. This fungus is often found in lawns, where shade trees have been removed and the roots left in the soil. Although not specific for Cottonwood (*Populus deltoides*) it was found growing commonly from the decaying roots of this species. Spore prints were made, by the following method, from fruiting bodies which had reached maturity but had not started to deliquesce. Portions of lamellae a few millimeters in area were removed with a small pair of forceps and placed on a microscope slide. Another slide, which had been previously washed, flamed and cooled was gently pressed to the upper surface of the lamella and a spore print resulted. These slides were stored in slide boxes until they were needed for further work. This was usually within a week of the time when the prints were made. After some practice, spore prints could be obtained in which the four spores from individual basidia retained their original position with respect to each other. These spores were later picked off the slides with a sharp needle as described below. Some experience was found necessary in selecting fruiting bodies in which the spores were in the proper stage of development to make spore isolation by this method possible. If too young, the spores were light colored and so delicate that they were mashed when touched with the isolation needle. If the fruiting

[1]Papers from the Department of Botany, Ohio State University, No. 384.

bodies were old, the spores were covered by the slime resulting from the deliquescence of the lamellae and adhered to the slide rather than to the needle. When of the proper age the spores were black in color, the spore print was dry, and the spores did not adhere in masses. At this stage individual spores adhered to the point of the isolation needle rather than to the slide and were easily removed.

For the reception of isolated spores, Petri dishes were prepared by cementing four ring cells in the bottom of each with beeswax. The covers were then placed on the dishes, which were sterilized in a hot air oven for one hour at 80 degrees centigrade. Square cover glasses, of dimensions which would cover the ring cells, were cleaned, flamed and cooled. In the center of each glass, a drop of dung agar was placed with a loop needle. The cover glasses with the agar drops on the lower surfaces were then placed over the ring cells in the Petri dishes. The dung agar used in this work was prepared by stirring up 300 gms. of fresh horse dung in 1 liter of water and filtering off the resultant liquid through cotton. To this was added 18 gms. of agar and the mixture heated until the agar dissolved. Where the medium was unusually opaque it was clarified with egg albumen. This is essentially the same medium as used by Newton (1926).

Working under a 16 mm. objective of the microscope, individual spores were picked up from the spore print slides with a sharp darning needle which had first been passed through several thicknesses of clean linen handkerchief. The 16 mm. objective gives ample working space between the lower face of the objective and the spore print slide. When a given spore was selected for transfer, all surrounding spores were first swept away with the needle. The needle was then cleared of spores by passing through the handkerchief several times and the desired spore touched with the needle, to which it adhered. When the spore had been picked up, the needle was thrust into a drop of agar on the lower surface of a cover glass, and the cover glass returned to its ring cell. The Petri dish, without cover, was then placed under the microscope and the drop examined through the cover glass to verify the spore transfer and also to make certain that no other spores had been transferred with the one desired. Since the spores were black and the medium clear amber in color, this could be easily done. In cases where the four spores of a single basidium were isolated,

these were placed separately in the four ring cells of one Petri dish. The spores were then examined daily until germination was observed, when the agar drops containing the germinated spores were transferred with a sterile needle to separate tubes of dung agar. By this method of spore isolation, which follows mainly that described by Hanna (1924), some 120 spores were isolated. Of these, 35 germinated and developed monosporous mycelia in the tubes to which they had been transferred.

These monosporous cultures were planted together in pairs on dung agar in plates. After a period of about one week, the mycelium in the plates was examined for the presence of clamp connections which is considered by most investigators to be evidence that hyphal fusion has occurred. In all, 79 of these pairings of monosporous mycelia were made and clamp connections were found to be present in abundance in 39 of the plates, while in 40, no clamp connections could be found. If the presence of clamp connections is an indication that hyphal fusion has occurred and is consequently a good criterion of the diploid condition of the mycelium resulting from certain of the pairings of monosporous mycelia, then monosporous cultures of *Coprinus micaceus* are unisexual rather than bisexual, since only those monosporous mycelia resulting from spores of opposite sex were capable of hyphal fusion. The unisexual nature of monosporous cultures of this species had previously been reported by Vandendries (1926) although this was unknown to the writer at the time.

An attempt was made to grow typical fruiting bodies of this fungus from mycelium which bore clamp connections. About one inch of sand was placed in the bottom of each of four small beakers and on this was placed one-half inch of a mixture of decayed cottonwood and horse dung. The beakers were then sterilized for one hour at 15 pounds pressure and, after cooling, agar from those Petri dishes which contained mycelium having clamp connections was placed on the mixture. The beakers were covered with cheese cloth and placed under one of the greenhouse benches. The cultures were watered with an atomizer through holes in the cheesecloth covers, care being taken not to saturate the soil. In about one month the first small "buttons" of the fruiting bodies appeared in two of the beakers. These later grew above the soil and expanded in the usual manner.

REFERENCES

Newton, Dorothy E. 1926. The bisexuality of individual strains of Coprinus Rostrupianus. Ann. Bot. 40: 105–128.

Hanna, W. F. 1924. The dry-needle method of making monosporous cultures of Hymenomycetes and other fungi. Ann. Bot. 38: 791–795.

Vandendries, R. 1926. La tétrapolarité des Coprinus. Bull. Soc. Roy. Bot. Belgique, 58: 180–186.

Tissue Immunity

Immunity has been studied from the humoral and cellular aspects for about forty-five years, but only recently has the importance of local tissue reaction been emphasized. Kahn's book is essentially a monograph embodying his own extensive and detailed experiments in this field. It deals principally with serological reactions and grossly observable tissue changes as they bear on the problem of tissue immunity. No histological studies are included. On the basis of this experimental structure the author considers various theoretical and clinical applications. The style leaves little doubt regarding the author's meaning but for the general reader the book is overburdened with experimental detail and repetition. For those in the immediate field who might wish to repeat or extend the work such detail would be essential.

The author holds that allergy and hypersensitivity are phases of immunity; that it is illogical to believe the host acts in a manner against his own interests (e. g., anaphylaxis) except when antigens are introduced in unnatural ways or amounts. He believes that the first and most fundamental evidence of an immune state is the capacity of tissue to anchor locally injected antigen. This is manifested usually by inflammation but if too much free antigen is present there may be necrosis. The appearance of humoral antibodies is secondary and they may disappear from the blood stream long before the capacity for tissue reaction is lost. In this sense incomplete proteins, such as gelatin, may act as antigens, for they are shown to be capable of evoking specific tissue response.

Effective use is made of an ingenious technic to follow local fixation of antigen. Rabbits are immunized against horse serum and then injected with diphtheria toxin. Now if antitoxic horse serum is injected into a certain tissue it will be more or less firmly anchored at the site of inoculation and will be unable to diffuse throughout the animal to neutralize the toxin. Accordingly much larger quantities of antitoxin will be required to prevent toxic death in the horse serum-immunized animals as compared with normals. The technic is applied to various tissues in various phases of active and passive immunity.

There can be no doubt that the author brings important experimental contributions to this field. One feels that he carries some of his theoretical applications rather far and occasional misconceptions are noted; for example, in the chapter on the reactions of young animals the inference is made that embryonic tissue possesses high defensive capabilities as compared with mature tissue. Yet there is little experimental evidence in the literature to support this assumption, in fact, the opposite seems more probable. The author refers repeatedly to the formation of insoluble immune globulin by local tissue cells, but there is no indication in the text that this is more than a mere hypothesis. In general, however, the speculative material is not introduced in an offensive manner but rather for the purpose of supplying a working basis for further thought and investigation. Immunologists and bacteriologists generally may profit by reading this work and clinicians too will find that it sheds new light on many phenomena with which they come into daily contact.—O. C. Woolpert.

Tissue Immunity, by Reuben L. Kahn. xix+707 pp. Springfield, Charles C. Thomas, 1936. $7.50.